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FURTHER CONSIDERATIONS ON THE ORIGIN OF THE ZONE OF ASTEROIDS AND ON THE CAPTURE OF SATELLITES.

BY T. J. J. SEE.

(*Read November 4, 1910.*)

In Volume II. of my "Researches on the Evolution of the Stellar Systems," 1910, which has just been published, I have treated at some length of the most important problems connected with the origin of the solar system, and have shown that as regards mode of origin the asteroids are connected with the periodic comets and have been gathered within Jupiter's orbit by the action of that great planet. This conclusion had been anticipated to some extent by the late Professor Stephen Alexander, of Princeton University, as far back as 1851, and more recently by the late Professor H. A. Newton, of Yale, and by the late M. Callandreau, of the Paris Observatory. The inferences of Newton and Callandreau resulted from their mathematical investigations of the perturbations of Jupiter upon small bodies crossing his orbit. Fortunately the weight of these eminent authorities is such that we need not dwell on the mathematical methods of reasoning employed. Our present aim is rather to examine briefly the consequences which follow from this theory, as developed in the second volume of my "Researches," and to make somewhat clearer the significance of certain observed phe-

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nomena of the solar system, by an argument so brief and so much to the point that even a layman may grasp it without difficulty.

1. It was pointed out by Oppolzer in 1880[1] that the resistance to two homogeneous spheres revolving in a discontinuous medium of cosmical dust is inversely as their radii, and therefore relatively very large for a small body and very small for a large one.[2] The secular effect of such a cause, therefore, is to make the small body approach the sun very rapidly, while it scarcely modifies the mean distance of the large body, the latter change being so small that it often may be neglected entirely.

2. Now if we contemplate the arrangement of the orbits of the asteroids in the solar system, we find them grouped almost entirely within Jupiter's orbit, in accordance with the mathematical investigations of Newton and Callandreau, and moreover spread over the entire zone from Jupiter to Mars, and even extending beyond these limits. Thus Eros has a mean distance slightly less than that of Mars, while the Achilles group of asteroids projects beyond the orbit of Jupiter. How much wider the zone may hereafter be found to be, it is difficult to predict.

3. Since the asteroids have been thrown just within Jupiter's orbit by the successive actions of that great planet, and subsequently had their mean distances so decreased with the lapse of ages as to carry them down to the orbit of Mars, it follows that this spreading of the asteroids over such a wide zone affords a clear and unmistakable illustration of the effects of resistance and collisions—these small bodies having approached the sun much more rapidly than the giant planet Jupiter which gathered them in. No other interpretation can be given to the great width of the asteroid zone. For the perturbative action of Jupiter could throw the asteroids but slightly within his own orbit, and the great decrease in the mean distances of many of them must be accounted for in some other way. We conclude, therefore, that the more rapid dropping of the asteroids towards the sun illustrates the secular effects of resistance in the form of cosmical matter, such as meteoric swarms and comets,

[1] Cf. *A. N.*, 2314 and 2319.

[2] Cf. my "Researches," Vol. II., p. 293.

which must occasionally be encountered by the asteroids as well as by Jupiter. In the long run the secular effects of collisions with comets and similar *isolated bodies* is exactly the same as the effects of a medium of cosmical dust of nearly *continuous character;* so that we need not dwell on the character of the medium.

4. It is important to notice that as the small masses approach the center most rapidly, they would tend in time to overtake the larger planets nearer the sun. Thus the moon may have had originally a greater mean distance than the earth, but by degrees it was brought so near our planet that it passed under the earth's control and became a satellite. A similar conclusion holds for all the other satellites of the solar system. Besides crossing over the orbits of the larger planets, owing to larger eccentricity, these smaller bodies were originally at greater distances than their several planets, and in approaching them by degrees were at length brought within the range of the planetary attraction and captured, as explained in Volume II. of my "Researches on the Evolution of Stellar Systems."

5. In the PROCEEDINGS of this society, 1910, p. 213, we have explained the process of capture by a direct and simple method of reasoning, and in view of the considerations just adduced, one cannot doubt that this represents essentially the process of nature. The lesson taught by the great width of the zone of the asteroids is so very significant that it may serve as a practical demonstration of certain tendencies in the physical universe. The same conclusion may be otherwise verified, from a new and independent point of view, as follows.

It is shown by the exact data calculated from Babinet's criterion that the planets never could have been detached or thrown off from the central mass of our system, but were formed at great distances and have gradually neared the sun, as its mass increased and they revolved in the nebular resisting medium and gathered up more and more cosmical dust.

6. Since, therefore, the solar nebula as a whole did not rotate fast enough to detach the planets, or even exert a sensible centrifugal force, but they were originally independent nuclei formed in

the remoter parts of the nebula, at a great distance from the center, it will be doubly obvious that these insignificant secondary nuclei in the outer parts of the nebula could not have rotated rapidly enough to detach their satellites. This is emphasized also by the retrograde motions of the outer satellites of Jupiter and Saturn, which are entirely inconsistent with any theory of detachment. Such a view would be nothing less than absurd. The relatively greater energy of axial rotation of some of the planets is to be explained by the capture of nebulous matter circulating as a vortex in the powerful field of the sun's attraction, owing to its immense mass, which gives the particles impinging against the planet great relative moment of momentum.

7. The column of the accompanying table designated "centrifugal force" gives the fractional part of the centrifugal force due to rotation, when the central bodies are expanded to fill the orbits of their attendant bodies as imagined by Laplace. In this table the unit in each case is the amount of centrifugal force required to set the body revolving in its present orbit. The excessively small value of the centrifugal force due to the rotation of the expanded central mass is very remarkable; and emphasizes strongly the untenability of the view that the attendant bodies were thrown off. Nothing more misleading than this traditional view ever became current in the literature of science; and yet it still circulates in all old works on astronomy, and probably it will take many years to get it eliminated from the current thought of our times.

8. There is another impressive way of illustrating the untenability of the now abandoned detachment theory, as follows: It is shown in works on celestial mechanics that

$$v^2 = k^2(1+m)(2/r - 1/a), \qquad (1)$$

where k^2 is the constant of attraction, m the mass of the attendant body, that of the central mass being unity, r is the radius vector, a the semi-axis major, and v the velocity. This gives for an attendant body of insensible mass

$$a = \frac{1}{\frac{2}{r} - \frac{v^2}{\cdot^2}}. \qquad (2)$$

As the orbits of the planets and satellites are essentially circular, we may put $r = a = 1$; and then since

$$a = \frac{1}{\frac{2}{r} - \frac{v^2}{k^2}} = 1,$$

it follows that in these units $v^2/k^2 = 1$. If instead of the velocity appropriate to carry the attendant body around in its nearly circular orbit, we substitute in (2) the fractional values of v^2/k^2 given in the above table, as due to the rotation of the central mass postulated by Laplace, we shall find that in all cases the semi-axis major of the new orbit is about one-half that of the existing orbit. The largest value results from the inner ring of Saturn, where the equation would give $a = 1/1.86 = 0.54$, the value of v^2/k^2 in this case being about 0.14.

TABLE OF DATA RELATING TO THE SOLAR SYSTEM.

Planet.	Cenrifugal Force, calculated from data of Babinet's criterion, present orbital centrifugal force being unity.	Density of Central Body, when expanded to fill orbit, that of atmospheric air at sea level being unity.
Mercury	0.000000253	0.001776
Venus	0.000000134	0.0002723
The Earth	0.000000098	0.0001029
Mars	0.000000064	0.00002913
Ceres	0.000000035	.....
Jupiter	0.000000019	0.000000732
Saturn	0.000000010	0.000000118
Uranus	0.0000000051	0.0000000146
Neptune	0.0000000032	0.0000000038

9. The obvious meaning of this result is that if the planets and satellites were projected along the tangents of their present orbits, with such small squared velocities as shown in the table, they not only would not pursue their present paths, but would in each case fall towards the centers and describe orbits with semi-axes just about one half. In other words, the projected satellites would pursue very elongated ellipses having their aphelia at the existing orbits, but their perihelia penetrating the central masses about which they now revolve. *In no case would over half a revolution be possible without collision, because the projected satellites would fall almost straight to the center and be absorbed in the central mass.*

If we compute the densities of the sun when expanded to fill the orbits of the planets, and of the several planets when expanded to fill the orbits of their respective satellites, we shall get the results given in the last column of the table. In considering this table it is sufficient to recall that an atmospheric pressure of 0.1 of a millimeter or a density of 1/7,600 that of air is a very high vacuum;

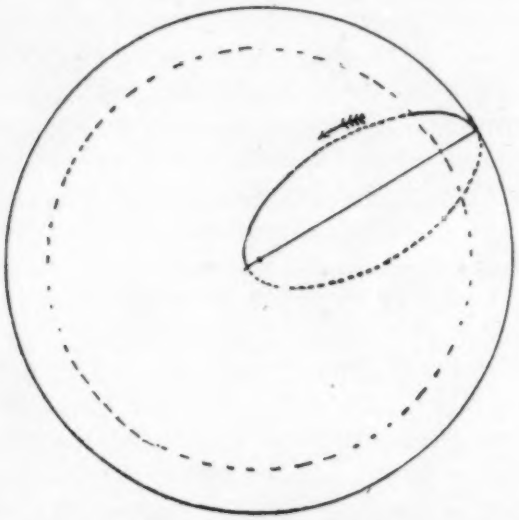

FIG. 1. Illustration of the motion of a particle projected along the inner edge of Saturn's dusky ring with velocity corresponding to planet's axial rotation when expanded to fill the ring. Pointed circle shows present dimensions of planet.

and since no greater hydrostatic pressure than this could be exerted from the center outward in case of most of the planets and many of the satellites as they fall unsustained by centrifugal force towards their dominant central masses, we see that these attendant bodies would in all cases fall practically without obstruction, and collision would in every case occur at the end of half a revolution. Could a more complete overthrow of the traditional detachment hypothesis of Laplace be imagined?

10. This affords an impressive illustration of the fallacy of the Laplacean theory of the origin of the planets and satellites; and

the only way we can explain the failure to detect this contradiction long ago is by the fact that Babinet's criterion seems to have been totally overlooked till taken up by the writer in 1908.

TABLE OF DATA RELATING TO THE SATELLITE SYSTEMS.

Planet.	Satellite.	Centrifugal Force, calculated from data of Babinet's criterion present orbital centrifugal force being unity.	Density of Central Body, when expanded to fill orbit, that of atmospheric air at sea level being unity.
The Earth.....	The Moon	0.00005657	0.01965
Mars.....	Phobos	0.001612	1151.
	Deimos	0.000644	73.05
Jupiter.....	V	0.034408	58.93
	I	0.014694	4.66
	II	0.009277	1.15
	III	0.005820	0.285
	IV	0.003323	0.0523
	VI	0.0005416	0.000232
	VII	0.0005217	0.000208
	VIII	0.0002254	0.0000169
Saturn.....	Inner Ring	0.1435	
	Mimas	0.048254	16.45
	Enceladus	0.037651	7.61
	Tethys	0.030436	4.11
	Dione	0.023772	1.96
	Rhea	0.017017	0.717
	Titan	0.0073449	0.0576
	Hyperion	0.0060716	0.0324
	Iapetus	0.0025205	0.00232
	Phoebe	0.0006962	0.000049
Uranus.....	Ariel	0.0055888	2.40
	Umbriel	0.0040111	0.88
	Titania	0.0024454	0.200
	Oberon	0.0018287	0.082
Neptune.....	Satellite	0.0017177	0.43

11. Since the attendant bodies could not be thrown off by rotation, and could not form where they now revolve out of mere scattered dust, owing to the feebleness of the mutual gravitation of such particles, under the powerful dispersive tidal action of the adjacent central masses, it follows incontestably that the planets and satellites have all been captured and added on from without. And we have explained the method of capture by simple and general considerations which make it certain that this process represents the true law of nature.

12. Any one who calculates the moment of momentum of orbital motion of a satellite such as the moon, which is 4.8 times larger than the present total moment of momentum of the earth's axial rotation, will perceive how powerfully the rotation of a planet may be accelerated by the impact of satellites against its surface. To be sure, the case of the moon is by far the most extreme in the solar system, owing to its large mass, but the tendency is the same everywhere, and really rapid rotations can be acquired only by the gathering in of quantities of satellites in the sun's field of force by large planets, as in the observed cases of Jupiter and Saturn.

The planets were formed at great distances from the sun, where the field of attraction would be much feebler than in their present situations; and hence nebulous matter collecting to such secondary centers in the outer parts of our nebula would give but feeble rotations of these masses about their axes; so that at no time in the past history of the solar system could a planet have rotated with sufficient rapidity to develop an appreciable tendency to detach a satellite. Such an hypothesis is wholly untenable, because it is found by calculation that the rapid rotations develop only when the planets are comparatively near the sun, and the relative moment of momentum of impinging particles therefore large.

Accordingly the simple considerations here adduced confirm from another independent point of view the results already obtained in second volume of my "Researches"; namely, that the moon and other satellites are merely captured planets, originally describing independent orbits about the sun; and show that the Capture Theory unquestionably is an ultimate law of nature.

U. S. Naval Observatory,
Mare Island, California,
October 17, 1910.

THE TRUE ATOMIC WEIGHTS OF OXYGEN AND SILVER.

By DR. GUSTAVUS HINRICHS.

(*Read December 2, 1910.*)

Chemists have been trying to determine the atomic weights of the chemical elements for now fully a century. Dalton introduced the idea in 1804, while Berzelius made the first reliable determinations as far back as 1814 and for a third of a century kept ahead of all others in this work.

While the laboratory work required for atomic weight determinations has been greatly improved since the time of Berzelius, the methods of reduction of the same by mathematical calculation have remained almost the same as those used by Berzelius a century ago. The work I have done in this line has hardly become known in this country, where the work done in one of the scientific departments at Washington, published by the Smithsonian Institution and disseminated under the official frank, continues to be upheld as the standard through the Committee on Atomic Weights of the American Chemical Society. But at the opening of the volume for the present year it is declared that "there is confusion and uncertainty throughout the table of atomic weights."[1]

It therefore seems desirable that this question be considered independent of the dominant chemical school by those who, like electricians and physicists, come in contact with the broad question of the constitution of matter which involves that of the atomic weights of the chemical elements.

In the old Berzelian calculations the atomic weight of oxygen is assumed as a fixed constant (100 by Berzelius, 16 at present) and all other atomic weights are referred to this standard. This system has led to the now "official" value 107.88 for silver, a value which I have repeatedly shown to be in conflict with the most renowned

[1] *Journal Am. Chem. Soc.*, 1910, p. 4.

recent determinations to the extent of over one tenth of one per cent.

This is not the place for renewing the discussion in detail; the publications in question are accessible to all. We would rather take up the question in the broadest way and try to decide it by a sort of crucial test. *We will show that the evidence on which the value 16 for oxygen rests is exactly the same as that which gives the value 108 for silver.*

It is a fact that all chemical reactions are approximately exact only and that all laboratory work is subject to the same limitation. It is therefore incorrect to assume that in the reactions and in the laboratory work there is involved no error whatever on the part of the oxygen and that all errors are due to the other elements associated with oxygen. It seems sufficient to state this to have it admitted.

But if oxygen be supposed free from all material imperfections, as is assumed in the common calculations, its actual shortcomings are not blotted out thereby—they are simply placed to the account of the other elements which are unfortunate enough to be in reaction with the supposedly perfect element, assumed to be immune from error by the school. Hence the errors of the associated elements will be correspondingly magnified. In this way, the dominant school now has arrived at the value 107.88 for silver.

Let us try to see how this has been brought about and how the question may be put in the above crucial form for decision.

It is agreed by all and not even denied by the American School that the atomic weight, for O = 16, is very near the round numbers: Ag 108, Cl 35.5, C 12, N 14, etc. These values we have called the *absolute atomic weights.*

Accordingly, the *true atomic weights* can differ from these absolute values by small fractions only; this we call the *departure* and designate by the letter epsilon (ϵ).

Hence the real mathematical problem is the *determination of the departure for each element in every reaction used.* We determine the departure in thousandths of the unit. Thus, if the American Chemical School be right in declaring that the atomic weight of silver is 107.88, the departure for silver would have the enormous value

— 120, while for the element oxygen in all reactions and in all determinations made by all chemists at all times and under all conditions the departure was zero always.

But is this introduction of the departure for the entire atomic weight not merely a formal matter? Not to the man versed in higher mathematics; for he knows that even the most complex functions permit a simple solution by proportional parts for all cases in which the increment of the variable is sufficiently small. Thus this solution would even hold true, with fair approximation, for the departure of 120 thousandths of a unit, above indicated. We may therefore express the difference between the Berzelian reduction maintained to the present day by the dominant school of chemistry and our own as corresponding to the difference between common algebra and higher mathematics.

While we have worked with the departures instead of the entire atomic weight for over twenty years, we had not been able to determine the relation between the different departures of the different elements in a given chemical reaction until we discovered the equation of condition in 1907. Since then we have determined the departures for each element in all the three hundred chemical reactions that have been used for the determination of atomic weights during the entire century. The results have been put into five tables, each giving sixty reactions. The first two of these tables have been published, the other three have been ready for publication since the close of 1909.

Now we may return to the point at issue, the value of the atomic weight of silver: is it 107.88 or is it 108, on the scale of 16 for oxygen?

Our tables show that oxygen occurs in 158 of the reactions used for the determination of atomic weights, while silver occurs 115 times. Consequently the atomic weight of oxygen has been determined 158 times and that of silver 115 times. Of course, the dominant school will declare that they have done no such thing; but that will not prevent us from using the data they have published although we will accept their declaration as made in good faith.

The following table gives the results obtained, as stated repeat-

edly: departures (expressed in thousandths of the unit) from the absolute values 16 and 108.

TABLE OF DEPARTURES ϵ (IN THOUSANDTHS).

Departures.	0–10	11–20	21–100	0–20	21–40	41–100	0–100	101–
OXYGEN.								
No. of cases	89	30	33	119	17	16	152	6
Mean ϵ	1	5	— 1	2	14	—17	1	
SILVER.								
No. of cases	39	22	36	61	22	14	97	18
Mean ϵ	—1	—5	—23	—2	—5	—54	—10	
No. per cent.								
Oxygen	58	20	22	78	11	11	100	4
Silver	40	23	37	63	23	14	100	18
Mean	49	21	30	70	17	13	100	—
All 656								
Determ. for all elements	49	21	30	70	18	12	100	7

An extended study of this table would be most instructive, but a brief summary must answer here.

It is noted that we have given two distinct sets of returns: by intervals of 10 and of 20 thousandths of the departure. In each set we have given only the first two intervals, putting all the others into a third column. The table itself shows the reason for these modes of record in *the great predominance of the small departures.*

This very predominance of the small departures means that the real departures are minute and the actual departures here tabulated as the results of the experimental work done during the century prove the absolute atomic weights to be the real atomic weights of nature. The question of a minute weight of the chemical valence, touched upon in our recent publications, does not come under consideration here.

The table shows that 50 per cent. of all cases give departures below 10 thousandths (0.01) and 70 per cent. below 20 thousandths (0.02) on all the 656 atomic weight determinations made by all the 300 reactions employed. This proves that the determinations have for their limit the absolute atomic weights themselves and that the departures represent mainly the imperfections of the experimental work.

The relatively few larger departures (only about 12 per cent.)

above 40 thousandths (0.04) are mainly due to the fact that we have taken all reactions used without excluding those known to be imperfect and which are generally excluded by others.

It will also be noticed that the mean departure for the greatest number of cases is only one or a few thousandths; it is without significance in the question here considered.

This question can now be fully answered. Bearing in mind that increased atomic weight necessarily brings a slight increase in the departures for experimental reasons, we must admit that *the departures for oxygen and for silver are essentially alike, so that the values* $O = 16$ *and* $Ag = 108$ *stand and fall together.* If oxygen is 16, then silver is 108, with nearly the same degree of precision. Again, if the value 108 is denied for silver, then the value 16 for oxygen is equally untenable.

Finally, it appears to me that it has been fully demonstrated that the assumption of immunity from error for oxygen is as false in fact as it is absurd in philosophy; possibly that accounts for the tenacity with which the school has clung to the same.

St. Louis, Mo.

THE PROPAGATION OF LONG ELECTRIC WAVES ALONG WIRES.

By E. P. ADAMS.

(*Read December 2, 1910.*)

In the usual deduction of the equations of propagation of electric waves along wires the notion of the electric constants per unit length is introduced. While there is no difficulty involved in this as far as resistance and leakage are concerned, the legitimacy of the extension of this notion to self-induction and capacity is not obvious. In order to determine the exact meaning to be attached to these terms it is convenient to consider a line in which the electric properties are localized in a finite number of coils, condensers and leaks, joined by ideal conductors of no resistance, self-induction and capacity. For the special case of long electric waves the solution can readily be obtained by means of the calculus of finite differences. On passing to the limit, by letting the number of coils, etc., increase indefinitely while their electric constants decrease indefinitely, the equations of propagation and their solution for a uniform line are at once obtained. There appears to be a considerable advantage in the use of this method in respect to its simplicity, particularly where the terminal conditions are at all complicated. Two problems are worked out in this paper; the first that of the free vibrations of a line earthed at both ends, and the second that of the forced vibrations when a periodic impressed electromotive force is applied to the circuit.

Consider a line of length l, in which are inserted at equal intervals n coils each of resistance R' and self-induction L. At points between each pair of coils one plate of a condenser of capacity S is connected, the other plate being earthed; and at the same points leaks to earth, each of conductance K', are introduced. The current in the kth coil is C_k, and the potential at a point between the

coils k and $k+1$ is V_k. For the first problem we then have $V_0 = V_n = 0$. Let L_1 be the coefficient of mutual induction between any coil and one of its nearest neighbors; L_2 the coefficient of mutual induction between the same coil and its next nearest neighbor but one, and so on. Similarly, let S_1 be the electric induction coefficient between any condenser and one of its nearest neighbors; S_2 the induction coefficient between two alternate condensers, etc. We can then write for the kth coil:

$$V_{k-1} - V_k = \frac{d}{dt}\Big(LC_k + L_1 C_{k-1} + L_1 C_{k+1} + L_2 C_{k-2} + L_2 C_{k+2} + \cdots\Big) + R'C_k \tag{1}$$

and for the kth condenser:

$$C_k - C_{k+1} = \frac{d}{dt}\Big(SV_k + S_1 V_{k-1} + S_1 V_{k+1} + S_2 V_{k-2} + S_2 V_{k+2} + \cdots\Big) + K'V_k \tag{2}$$

Now in the case of long electric waves the currents in any coil and its near neighbors will be very nearly the same. The terms in the series in (1) containing currents in distant coils become relatively unimportant on account of the diminution of their coefficients. In this special case it will therefore be legitimate to replace the series by a single term and we can therefore write:

$$V_{k+1} - V_k = L' \frac{d}{dt} C_k + R' C_k, \tag{3}$$

in which L' may be termed the effective coefficient of self-induction of any one of the coils. When we pass to the limit by increasing indefinitely the number of coils, etc., and at the same time decreasing indefinitely all the electric constants, the limiting value which the product of L' by the number of coils in a unit length approaches will be the self-induction per unit length of the uniform line. Equation (2) modified in an analogous manner reduces to:

$$C_k - C_{k+1} = S' \frac{d}{dt} V_k + K' V_k \tag{4}$$

Subtracting the equation for the coil $k+1$ from (3) and substituting from (4), we get:

$$V_{k-1} - (2+h)V_k + V_{k+1} = 0, \tag{5}$$

where

$$h = R'K' - L'S'p^2 + ip(L'K' + R'S'), \tag{6}$$

in which it is assumed that the potentials and currents all vary as e^{ipt}. (5) is a linear difference equation of the second order. By the usual method we put

$$V_k = A_k \alpha^k e^{ipt},$$

and find:

$$\alpha = \frac{2+h}{2} \pm \tfrac{1}{2}\sqrt{4h + h^2}. \tag{7}$$

Let these two values be α and β, the former with the positive sign of the radical. In general α and β are different, and so we get the two distinct solutions required by an equation of the second order. But for $h=0$ or $h=-4$ α and β have the same values. The complete solution of (5) is therefore:

$$V_k = (A_1 + B_1 k)e^{ip_1 t} + (A_2 + B_2 k)e^{ip_2 t} + (A_3 + B_3 k)(-1)e^{ip_3 t} + (A_4 + B_4 k)(-1)^k e^{ip_4 t} + \Sigma(A_p \alpha^k + B_p \beta^k)e^{ipt}.$$

Since $V_0 = V_n = 0$, whatever t, $A_1 = A_2 = A_3 = A_4 = B_1 = B_2 = B_3 = B_4 = 0$; $A_p + B_p = 0$ and

$$\alpha^n - \beta^n = 0. \tag{8}$$

Let now

$$h = -4\sin^2\theta, \tag{9}$$

(7) reduces to

$$\alpha, \beta = \cos 2\theta \pm i \sin 2\theta, \tag{10}$$

and (8) gives

$$\theta = \frac{m\pi}{2n}, \tag{11}$$

where m is any integer. $m=0$ and $m=n$ are excluded because these give $h=0$ and $h=-4$, which are already disposed of. If we take $m=n+1$, $n+2$, etc., we get the same series of values

obtained from $m=1$ to $m=n-1$. We thus get:

$$V_k = \sum_{m=1}^{m=n-1} A_m \sin\frac{km\pi}{n} e^{ip_m t}. \tag{12}$$

A_m and p_m are complex quantities. Writing $p_m = p_m' + ip_m''$, we get from (6), (9) and (10):

$$p_m' = \sqrt{\frac{4\sin^2\frac{m\pi}{2n}}{L'S'} - \frac{(L'K' - R'S')^2}{4L'^2S'^2}}, \tag{13}$$

$$p_m'' = \frac{L'K' + R'S'}{2L'S'} = p''. \tag{14}$$

p_m'' is thus independent of m. The real part of (12) may now be written

$$V_k = e^{-p''t}\sum_1^{n-1} A_m \cos(p_m' t - \phi_m)\sin\frac{km\pi}{n}, \tag{15}$$

where A_m and ϕ_m are new arbitrary real constants.

The currents in the several coils may be obtained from (3) combined with (12). Taking the real part we find

$$C_k = e^{-p''t}\sum_1^{n-} B_m \cos(p_m' t - \psi_m)\cos(2k-1)\frac{m\pi}{n} \tag{16}$$

where B_m and ψ_m are known in terms of A_m and ϕ_m in (15).

The last four equations give the complete solution of the problem. The constants A_m and ϕ_m may be determined by Fourier's method when the initial conditions are known.

Now let n increase indefinitely while R', L', S' and K' all decrease indefinitely. Let $L = \text{limit } L'n/l$, and similarly for the others. Let δx be the distance between two coils, so that $n\delta x = l$. Measuring x from the end of the line corresponding to $k=0$, we have $k = nx/l$ and we get in the limit:

$$V = e^{-p''t}\sum_1^{\infty} A_m \cos(p_m' t - \phi_m)\sin\frac{m\pi x}{l}, \tag{17}$$

$$C = e^{-p''t}\sum_1^{\infty} B_m \cos(p_m' t - \psi_m)\cos\frac{m\pi x}{l}, \tag{18}$$

$$p_m' = \sqrt{\frac{m^2\pi^2}{l^2LS} - \left(\frac{LK - RS}{2LS}\right)^2}, \tag{19}$$

$$p'' = \frac{LK + RS}{2LS}, \tag{20}$$

which are the well-known solutions for the free vibrations of a uniform line for long waves.

The differential equation of which (17) is the solution is obtained by passing to the limit in the difference equation (5). We thus get

$$\frac{\partial^2 V}{\partial x^2} = LS\frac{\partial^2 V}{\partial t^2} + (LK + RS)\frac{\partial V}{\partial t} + RKV.$$

Equations (3) and (4) on passing to the limit give:

$$-\frac{\partial V}{\partial x} = L\frac{\partial C}{\partial t} + RC,$$

$$-\frac{\partial C}{\partial x} = S\frac{\partial V}{\partial t} + KV.$$

For the second problem, that of a periodic impressed electromotive force applied to one end of a line, the other end being earthed, we have to solve equation (5) subject to the conditions:

$$k = 0, \quad V_k = Ee^{i\nu t}, \qquad k = n, \quad V_k = 0. \tag{21}$$

The resulting solution may of course be applied to a closed circuit with the periodic force $Ee^{i\nu t}$ introduced in it at any point. After the free vibrations have been damped out, the solution will be

$$V_k = (A\alpha^k + B\beta^k)Ee^{i\nu t},$$

where A and B are arbitrary constants and α and β are given by (10). Determining A and B by means of (21) we get

$$V_k = \frac{\sin 2(n-k)\theta}{\sin 2n\theta}Ee^{i\nu t}. \tag{22}$$

θ is a complex angle defined by (6) and (9) if ν is written for p

in (6). Putting $\theta = \theta' + i\theta''$, we get as the real part of (22)

$$V_k = \frac{E}{2(\cosh 4n\theta'' - \cos 4n\theta')}\{e^{2(2n-k)\theta''}\cos(vt + 2k\theta') + e^{-2(2n-k)\theta''}\cos(vt - 2k\theta') - e^{2k\theta''}\cos(vt + 4n\theta' - 2k\theta') - e^{-2k\theta''}\cos(vt - 4n\theta' + 2k\theta')\}, \quad (23)$$

which together with

$$4(\sin^2\theta'\cosh^2\theta'' - \cos^2\theta'\sinh^2\theta'') = v^2L'S' - R'K' \quad (24)$$

$$-4\sin 2\theta'\sinh 2\theta'' = v(L'K' + R'S') \quad (25)$$

gives the complete solution.

Now on passing to the limit as before, we can replace $\sin\theta$ by θ, $L' = L\delta x$, etc., and we find

$$2\theta' = -Q\delta x,$$
$$2\theta'' = P\delta x,$$

where

$$P,\ Q = \frac{1}{\sqrt{2}}\{(v^2L^2 + R^2)(v^2S^2 + K^2) \pm (RK - v^2LS)\}^{\frac{1}{2}},$$

We thus have

$$4n\theta'' = 2Pl, \quad 4n\theta' = -2Ql,$$
$$2k\theta'' = Px, \quad 2k\theta' = -Qx;$$

(23) thus reduces to

$$V = Ee^{-Pz}\cos(vt - Qx) + \frac{Ee^{-Pl}}{2(\cosh 2Pl - \cos 2Ql)^{\frac{1}{2}}} \times \{e^{Pz}\cos(vt + Qx + \phi) - e^{-Pz}\cos(vt - Qx + \phi)\},$$

where

$$\tan\phi = \frac{\sin 2Ql}{e^{-2Pl} - \cos 2Ql},$$

which is the solution for this case as given by Heaviside,[1] except that leakage is here considered and the real impressed force is $E\cos vt$ instead of $E\sin vt$.

[1] "Electrical Papers," Vol. 2, p. 62.

PRINCETON UNIVERSITY.

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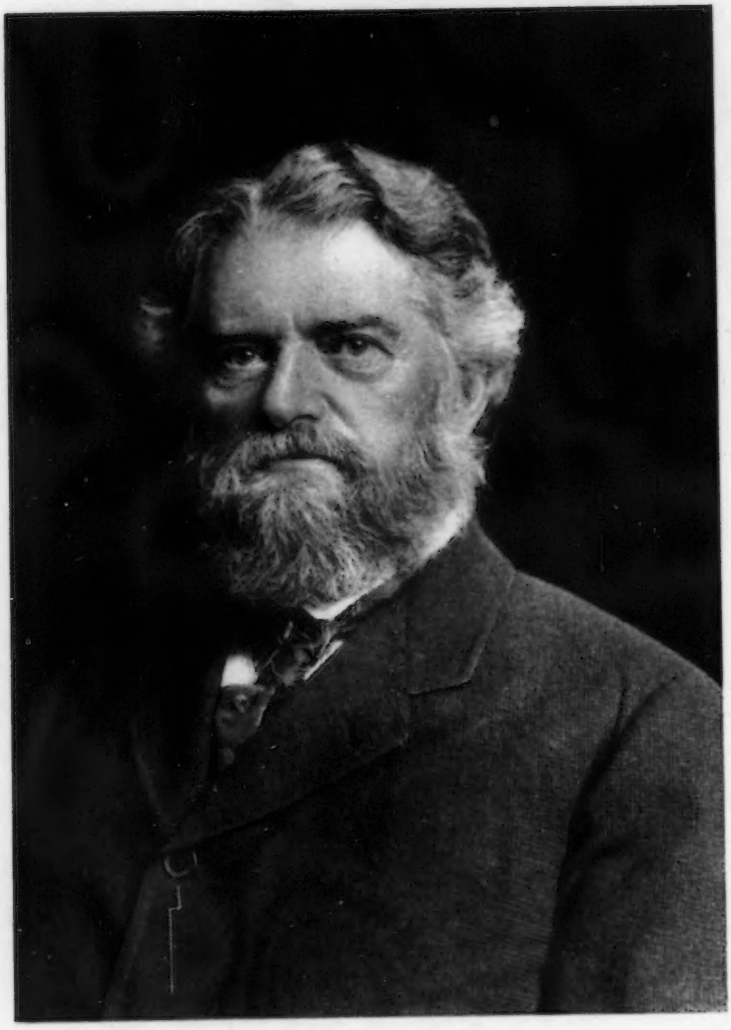
OBITUARY NOTICES OF MEMBERS DECEASED.



Simon Newcomb

SIMON NEWCOMB, F.R.S., LL.D., D.C.L.

(Read April 23, 1910.)

The subject of this sketch, Simon Newcomb, furnishes a conspicuous instance of a career carved out by the man himself. Born March 12, 1835, in what seems to us a remote region of Nova Scotia, with nothing in his early history to suggest much beyond a perpetual struggle for existence, he, nevertheless, by the exercise of great natural talent, with undaunted pluck and perseverence, succeeded in attaining a place in the front ranks of his favorite science, that science which some of us, at least, consider the noblest of all—namely astronomy.

Though born in Nova Scotia, Professor Newcomb's ancestors were of that sturdy New England stock which his furnished so large a proportion of our distinguished men, and which has contributed so powerfully toward making our nation what it is to-day.

In his remniscences, Professor Newcomb says:

> So far as the economic conditions of society and the general mode of thinking were concerned, I might lay claim to have lived in the time of the American Revolution. A railway was something read or heard about with wonder, a steamer had never ploughed the waters of Wallice Bay. Nearly everything necessary for the daily life of the people had to be made on the spot and even at home.

It was in this environment of Arcadian simplicity that young Newcomb passed his early years. His father's occupation was that of school teacher—not a lucrative one, and made even less so by the fact that he had ideas of his own on the subject of education which were not in strict harmony with those of his contemporaries. Wealth and poverty are, however, relative terms, and this early period which, from our point of view, would no doubt appear to be one of considerable privation, was probably not so regarded by those immediately concerned.

Such were the surroundings in which the first sixteen years of young Newcomb's life were passed. Where everyone labored from daylight to dark, his lot could not be expected to form an exception.

The future seemed to have only the vaguest prospects of any other lot. His father indeed spoke of an ambition to see him a prominent lawyer, while it was his mother's wish that he should become a clergyman, although she feared that he would never be good enough. In his own day dreams, he was a farmer, driving his own team, although he appears never to have found himself in harmony with this mode of life, being greatly mortified at his want of skill, particularly in the art of driving oxen.

At the age of sixteen, an opportunity presented itself which seemed to offer a solution of the problem of a career for the future, more in keeping with the tastes of a young man like Mr. Newcomb, than the life of a farmer. This was an arrangement with a quack doctor, Hershay by name, by which Newcomb was to live with the former until of age, assisting about the house and office in whatever way he could, in return for which the doctor was to teach him what he knew of medicine. It cannot be said that the doctor failed to carry out this part of the contract, but as a guide and example at this formative period of a young man's life, nothing could be more pernicious. On the only occasion when the doctor expressed himself freely to his pupil, he gave his views as to the true secret of success as follows, "The world is all a humbug and the biggest humbug is the best man." As for Newcomb, it seems very unfortunate that he should have wasted two years of his life with the petty drudgery of this position, when he was so obviously receiving nothing in return. The relation was, however, terminated by Newcomb, two years before the expiration of the contract by the simple and effectual process of running away. In due time, he joined his father at Salem, Massachusetts, who had decided to try his fortune in the states, his mother having died some years before. Before very long the young man found himself in charge of a country school, at a place called Massey's cross roads, and later at Sudlersville, Kent County, on the east shore of Maryland.

This may be considered as the beginning, though an humble one, of a new order of things, the outcome of which was to be the distinguished scientist as we know him, the recipient of the highest honors and distinctions which the world of science and culture had to bestow.

In Newcomb's accounts of the early years of his life we are impressed by the small amount of encouragement and assistance which he found in his vague aspirations toward something better. He seems to have read everything that came within his reach. This included a number of very uninviting works on geometry and algebra, navigation and the like, which very few boys would have the courage to attempt without a teacher. But the entire absence of anyone capable of directing him in his studies, is perhaps even more marked than the absence of books. Everyone in this primitive region where his early life was passed, seems to have been so absorbed in the struggle for existence that very little energy remained for anything else. If during the first eighteen years of his life, he ever met anyone who had seen a college, I have found no mention of the fact.

In 1856 Mr. Newcomb found himself teaching in the family of a planter named Byran, fifteen or twenty miles from Washington. He could, therefore, readily visit this place at frequent intervals. He tells us that, up to this time, he is not aware that he had ever seen a real live professor. He had, however, had a little correspondence with Professor Henry, which is so characteristic of the kindly and genial nature of the latter as to be worth relating. While teaching at Sudlersville, Mr. Newcomb made what appears to have been his first serious attempt at an original mathematical investigation, viz., "A New Demonstration of the Binomial Theorem." This he sent to Professor Henry, asking whether he considered it suitable for publication. Instead of consigning it to the waste paper basket and giving it no further attention, as many a man in Professor Henry's position would have done, he gave a negative reply, but as mathematics was not his specialty, offering to submit the document to some one better informed than himself in such matters. As was to have been expected, an adverse report came to hand in due time, which Professor Henry transmitted, accompanied by a pleasant note from himself to the effect that, although not so favorable as might have been expected, it was sufficiently so to encourage further effort. Soon after this Mr. Newcomb took what was for him the bold step of calling on Professor Henry, who not only received him with

characteristic kindness, but in due time introduced him to Professor Hilgard, of the Coast Survey, who in turn introduced him to Professor Winlock, of the "Nautical Almanac."

At this time the headquarters of this publication were at Cambridge, Mass. Encouraged by a note from Professor Henry, Mr. Newcomb started for Cambridge in December, 1856, hoping to find employment. After some delay, he was finally installed as computer at a salary of thirty dollars a month. Humble as this may appear to us, the day of receiving the appointment was probably the happiest of his life up to this time. Professor Newcomb speaks of his first arrival at this destination as follows:

> I date my birth into the world of sweetness and light on one frosty morning in January, 1857, when I took my seat between two well-known mathematicians, before a blazing fire in the office of the Nautical Almanac at Cambridge, Mass. The men beside me were Professor Joseph Winlock, the superintendent, and Mr. John D. Runkle, the senior assistant in the office.

Nearly five years were passed here amid surroundings which were very pleasant and agreeable, the more so by contrast with Mr. Newcomb's former life. They were years of education and development, the opportunities being peculiarly favorable. No fixed hours of attendance were required at the office. If the work assigned was due satisfactorily, that seems to have fulfilled every requirement. This made it possible for Mr. Newcomb to become a student in the Lawrence Scientific School, from which he graduated in due time. His course was naturally largely mathematical under the direction of the well-known Benjamin Peirce. The number of students at this time, following this line of work was naturally small, but Professor Peirce's abstruce lectures found at least one appreciative listener. We naturally feel considerable pride in the prominent place which American astronomy and astronomers occupy in the world today. Matters were, however, very different in this respect fifty-five years ago. It was about this time that the situation was summed up as follows by a German "Gelehrte," who had recently visited this country, "You have one astronomer, Professor Peirce, and no mathematicians." The prediction of Alexis de Tocqueville, that the conditions of life in America would never be favorable to the

development of eminence in science, seems to have been tacitly accepted by many as practically disposing of the matter.

The beginnings of physical science in America have been compared to the birth of Minerva as she sprang fully armed from the brain of Jove. The simultaneous appearance, here in Philadelphia, of Franklin, Rittenhouse and William Smith, at once brought this country to the notice of the devotees of science in Europe. The interest taken in the transit of Venus in 1769, for observing which elaborate preparations were made in Philadelphia, brought astronomy to the front, with plans for a first class astronomical observatory with, presumably, Rittenhouse as director. This project was probably premature, but in any case the approaching revolution soon absorbed all the energies of the country, and three quarters of a century was destined to elapse before anything like a general revival of interest in this subject took place. At the time of which we are speaking, however, the movement was well under way, and the men with whom Mr. Newcomb was associated at Cambridge including more than one name destined to achieve international reputation. A number of observatories were in more or less active operation but, as yet, little had been produced which could bear comparison with the best work in Europe.

The work, however, was well begun, but was no doubt destined to be somewhat retarded by the Civil War—the preliminary skirmishes were even now being fought in Kansas and elsewhere. But the times were ripe for an advance and it could not again be suppressed.

On July 17, 1860, occurred a total eclipse of the sun. The path of totality passed across British North America, touching southern Greenland, thence across the Atlantic to Spain. Mr. Newcomb was one of a party organized for observing the eclipse. The point chosen was on the Saskatchewan River, about as inaccessible and remote from civilization at that time as central Africa is today. The journey lay from St. Paul across Minnesota by stage, thence down the Red River by steamer, across Lake Winnipeg and up the Saskatchewan by birch bark canoe. Unexpected delays and difficulties seemed likely to prevent the party from reaching its destination in time for the eclipse. By heroic exertion on the part of the half

breeds who paddled the canoe, however, they arrived at the place selected on the evening before the eclipse was to take place. Clouds, however, covered the sky so that nothing could be done, a not uncommon experience in such cases.

In 1861 Mr. Newcomb was informed of a vacancy in the corps of professors of mathematics attached to the Naval Observatory at Washington, with the suggestion that he should apply for the place. Although the desirability of some position of greater prominence and with a better outlook for the future was not new, still the surroundings and attractions at Cambridge were so congenial that the thought of severing them was not an agreeable one. After some hesitation, however, Mr. Newcomb made formal application for the professorship and, as he confesses, was greatly surprised to receive, a month later, his commission, duly signed by Abraham Lincoln.

The duties at the Washington Observatory were of a character entirely new to Mr. Newcomb. The use of instruments in practical work was entirely outside his experience. In fact, with the exception of two or three visits to the Cambridge Observatory, he had never been inside such an establishment. Nor had he any particular liking for this kind of work, which, it must be confessed, involves a great amount of drudgery, and interferes sadly with continuous theoretical investigation.

The Washington Observatory was at that time practically the only place in the country where continuous observation was carried on. The principal instruments consisted of a mural circle in charge of Professor Yarnall, with the necessary clocks and subsidiary apparatus. In point of accuracy and precision, these were not what we should call first class instruments. But the methods followed were even worse than the instruments. Each observer pursued his own plan, observing what he pleased and when he pleased, with no uniformity of program, employing no uniform system of reduction, so that anything like homogeneity of results was out of the question. To add to the difficulty, the observatory was situated in a malarial district near the Potomac, far from the resident quarter of the city, so that the observers were compelled to walk from one to three miles through muddy streets in going and returning from work.

Mr. Newcomb was at first assigned to duty as assistant to Professor Yarnall on the transit instrument. The results of this system or want of system, were afterwards published, forming the Washington catalogue of 10,964 stars, commonly known as "Yarnall's catalogue." Though by no means worthless, this is far from possessing the value which it should have had. The work done at Greenwich, for instance, at the same time, was much superior.

It is to be remembered that, at the period of which we are now speaking, the Civil War was raging at its greatest fury. Washington was the center of gigantic military operations which seemed to overshadow everything else. But those in authority took a certain pride in having this work kept up without interruption during the conflict. On one occasion only does the serenity, supposed to attend scientific pursuits, seem to have been seriously disturbed. This was on the occasion of the noted raid of General Early in 1864. The defeat by the latter of General Lew Wallace seemed to leave the way open to Washington. It is an open question whether the city might have been taken by a rapid dash on Early's part at this time. Under these conditions, all who were in the service of the war and navy departments were ordered out to assist in manning the entrenchments which were the only defence of the city. The detachment to which Professor Newcomb was assigned was ordered to Fort Lincoln, where for two days they waited an attack by Early. Meanwhile reinforcements arrived from Fort Monroe and Early abandoned any design which he may have had for an attack.

Captain Giliss, the superintendent of the observatory, was an astronomer of distinction. Previous to his taking charge of this work, he had made many thousands of observations. He was naturally much interested in the improvement of the unsatisfactory state of affairs, but it was not an easy matter, in these exciting times, to accomplish much. At length, in 1863, he obtained authority to procure a meridian circle of the highest order of excellence, which was finally completed and ready for active service on January 1, 1866. Professor Newcomb was placed in charge with three assistants. An elaborate program of fundamental work was adapted to be carried out on a uniform plan for three years. This involved continuous attendance on the part of one or another of the observers,

both day and night whenever the weather permitted observation. Much was expected in the way of results, superior perhaps to anything before attained, but these anticipations were not fully realized. The instrument itself was not what had been expected and the mounting proved unstable, so that the results, instead of the superiority which had been looked for, proved inferior to those reached at the European observatories.

When a large telescope was installed at Washington toward the end of 1875, Professor Newcomb was placed in charge of the instrument, which at his request was turned over to Professor Hall two years later. This closed Professor Newcomb's activities in the way of systematic observation.

In 1869 he made application to be transferred to the office of the "Nautical Almanac," with the understanding that his time should be devoted to an investigation of the moon's motion, a problem in which he had become greatly interested. Doubtless there is room for honest difference of opinion as to the relative importance of the two branches of astronomical work, but if the lunar problem was to have been taken hold of at this time, there is no question as to whom it should have been entrusted. Men could be found in plenty who were capable of reaching valuable results in the field of observation, but those who were capable of attacking with success the most intricate of all astronomical problems, the lunar theory, have always been extremely few. The transfer to the "Nautical Almanac" was not made, but the arrangement which resulted was probably even more satisfactory. A few years before Newcomb began his work on the moon, the lunar tables of Hansen had been published. They were based on a part only of the Greenwich observations from 1750 to 1850, and represented with practical accuracy the moon's motions for this period of a full century. But, in the course of a very few years, the actual position was found to deviate very appreciably from those given by the tables, the deviations increasing from year to year. What the state of things previous to 1750 had been was a very interesting question, but one not easy of solution, as very little material accurate enough for such an investigation was known to exist.

The ordinary meridian determinations, before the time of Bradley, 1750, were of very little use for a refined investigation like this. Another class of observations, however, furnished data comparable in accuracy with the best determinations made today, that is, the occultations of stars and planets by the moon. Though but few such had ever been published, it occurred to Professor Newcomb that among the unpublished work at the European observatories, possibly enough such data might be found to repay the labor involved in the search. The result exceeded his most sanguine expectations. At the Paris observatory, in particular, data were brought to light which carried the period of accurate lunar observation back nearly a century, so that now instead of a lunar theory, which like that of Hansen depended on one hundred years of observation, we have available two hundred and fifty years of accurate data.

It is interesting to know that this work at the Paris Observatory was carried on while the struggle with the Commune was at its height, the windows frequently rattling with the reports of cannon.

The lunar theory, as it is called, seems to have been the problem of Professor Newcomb's predilection. Besides the researches already mentioned which involved a great amount of time and labor he wrote, together with other papers, an elaborate memoir dealing with the action of the planets on the moon. He did not attempt, however, a complete revision of the subject. His most important services in this direction were in what has been styled the border land between the theoretical and practical, viz., that of assembling all available data and comparison with theory, thus exhibiting in a concise manner precisely what remains to be accomplished in order to bring the two into harmony.

The last of his published papers is found in the *Monthly Notices of the Royal Astronomical Society* for January, 1909, exhibiting the deviations of the mean longitude of the moon from the position given by theory. The explanation of these discrepancies now constitutes one of the most interesting of the unsolved problems of astronomy.

The theoretical researches in the lunar theory have been greatly extended by the classic work of Mr. George W. Hill, while the

prodigious labor involved in applying the latter to the derivations of new tables of the moon's motion is being well taken care of by our fellow member, Professor Ernest W. Brown.

In September, 1877, occurred an event which had been long anticipated, viz., the retirement of Professor Coffin from the directorship of the "Nautical Almanac," and the appointment of Professor Newcomb to this position. Meanwhile, in 1875, the directorship of the Harvard College Observatory became vacant by the death of Professor Winlock. Soon after, Professor Newcomb was surprised to receive from President Eliot a letter offering him the position. Although, as has been said already, the practical work of an observatory was not the line of activity which appealed most strongly to Professor Newcomb's tastes, a professorship at Harvard, with all that this implies, was not to be lightly disregarded. There was, moreover, opportunity for escape from the political atmosphere with all its petty annoyances, attendant on a government position at Washington.

I do not know that Professor Newcomb was ever fully convinced that he had chosen the better course in declining this offer, though he disposes of the matter very modestly as follows: "No one who knows what the Cambridge observatory has become under Professor Pickering can feel that Harvard had any cause to regret my decision."

The directorship of the "Nautical Almanac" now gave Professor Newcomb the long-wished-for opportunity to take up seriously the herculean task of a complete revision of the entire subject of exact astronomy. Only those who have had some experience in these matters can form any adequate conception of what this involved. The vast field of stellar astronomy, of the planetary and lunar motions, had been cultivated since the time of Hipparchus by many of the ablest minds which the world has produced. As, however, each investigator usually carried on his work independently of the others, there was great want of consistency and homogeneity in the mass taken as a whole. Professor Newcomb may not at first have planned so large an undertaking, but this is the form which it assumed. For twenty years, during which he remained at the

head of the "Nautical Almanac," assisted by a small army of aids and computers, including at least one man of international reputation, and at one time or another a dozen line officers of the navy, this work went steadily forward.

All who are in any way interested in the professional work of astronomy are familiar with some part at least of the eight quarto volumes of astronomical papers of the "American Ephemeris" which contain the most important results of this undertaking. This is not the place for an analysis of the contents of these volumes or for more than the briefest outline of the work attempted. It may be said that it involved a complete investigation of the orbits of the principal planets, on a uniform plan employing a strictly homogeneous system of constants derived from practically all existing data. For the latter purpose, the number of observed positions of the sun, Mercury, Venus and Mars alone numbered 62,030, made at thirteen different observatories. The investigations for these inner planets, and the two outer ones, Uranus and Neptune, were made by Professor Newcomb himself or under his personal direction. That of Jupiter and Saturn was entrusted entirely to Mr. George W. Hill. A man more competent could not have been found on either side of the Atlantic. Without his valuable assistance, it would hardly have been possible to bring the task to a successful close. Redeterminations of the solar parallax, the constants of precession, nutation and abberration were involved directly or indirectly in the undertaking, together with an elaborate investigation of the places of the fixed stars, on which, in the last analysis, all else depends.

This work, which has been outlined, was near completion when the time for retirement under the age limit arrived. Doubtless, Professor Newcomb would have preferred to remain at his post some time longer, but the law was inexorable.

His retirement did not, however, imply cessation from activity. Arrangements were made by which this great work was brought to a practical completion. The lunar researches were provided for by a grant from the Carnegie fund, and were completed only a short time before his death, under conditions of physical suffering, such that very few would have had energy for any purpose.

Besides the activities which have been briefly outlined in what precedes, Professor Newcomb was more or less directly connected with a large number of scientific undertakings, particularly with many astronomical enterprises of importance in which this country was concerned. He was secretary of the Transit of Venus Commission in 1874 and 1882, and was in charge of a party in 1882 for observing the transit at the Cape of Good Hope. This event attracted much attention at the time and there seems to have been no difficulty in obtaining from Congress appropriations aggregating $375,000 for the purpose. Yet a small sum of perhaps $5,000 for preparing the results for publication has never been forthcoming. The work has consequently never been published and there is little prospect that it ever will be.

Professor Newcomb also took part in several eclipse expeditions, one of which, that of 1860, has already been mentioned. He was, to a great extent, responsible for the planning and installing of the large telescope at the Washington Observatory, at that time the largest refracting telescope in the world. The details of location, construction and equipment of the Lick Observatory were settled, for the most part, by his advice in coöperation with Professor Holden, its first director.

Professor Newcomb was appointed professor of mathematics and astronomy at the Johns Hopkins University in 1884, as successor to Professor Sylvester. His duties as teacher closed in 1894. In 1900 he was made professor emeritus. He was editor of the *American Journal of Mathematics* from 1884 to 1894, and during 1899 to 1900.

Professor Newcomb was president of the American Association for the Advancement of Science in 1876 and 1877, of the Astronomical and Astrophysical Society of America from its beginning in 1899 until 1905, of the American Mathematical Society, the Society for Psychic Research, and chairman of a great number of scientific assemblages and congresses, the most important of which was perhaps the International Congress of Arts and Sciences, held at St. Louis in 1906 in connection with the exposition, the complete success of which was due more than anything else to his world-wide repu-

tation and to the untiring energy with which he planned and carried out the undertaking.

Professor Newcomb was a recipient of honorary degrees from seventeen American and foreign universities; academies and scientific organizations throughout the world honored him with membership, decorations and medals, until the supply was almost exhausted. Among others, he was one of the eight foreign associates of the Institute of France, a distinction which had come to no other American scientist since the time of Franklin. He was commander of the Legion of Honor of France. From the German Emperor he received the highest honor which he could bestow, viz., Knighthood for Merit in Science and Art, a distinction held by no other native American. The complete list is too long for this time and place.

He was presented to Emperor William, to King Edward, the kings of Italy and of Sweden, and the president of the French Republic.

A complete bibliography of Professor Newcomb's writings embraces about four hundred titles. A large variety of subjects, practically every phase of astronomical science, received some attention. Many of these works are elaborate treatises embodying the labor of years. There are papers on pure mathematics, on political economy, in which he was greatly interested, series of astronomical and mathematical text-books, and many books and magazine articles of a popular or semi-popular nature. The following are a few specimen titles: "Reminiscences of an Astronomer," "Sidelights on Astronomy," The A. B. C. of Finance," "Principals of Political Economy," "A Plain Man's Talk on the Labor Question," "Popular Astronomy," "Astronomy for Everybody." Translations of his books are to be found in the German, Russian, Dutch, Norwegian, Bohemian and Japanese languages.

Professor Newcomb's ability to concentrate his attention strictly on the matter in hand was a very important factor in accomplishing what he did. This perhaps gave an impression of indifference and unsociability in the minds of those who knew him only casually. Naturally he had little patience with the too numerous class of charlatans and cranks who are always ready to waste the time of a

man of any prominence in expounding their peculiar views, but those who sought his advice and encouragement in reference to a matter of any importance found him more than ready to give such assistance as lay in his power.

His busy life naturally limited his social activities. He cared little for fashionable gatherings, but he greatly enjoyed the company of congenial minds, and many men of science, residents of Washington, and visitors from other places, can testify to the hospitality with which they were entertained at his home. He was very fond of history and poetry, his favorite poems seem to have been memorized with very little effort. Addison's Ode, "The Spacious Firmament on High," especially the closing lines, appears to have given him great pleasure:

> "What though in solemn silence all
> Move round the dark terrestrial ball?
> What though no real voice nor sound
> Amid their radiant orbs be found?
> In reason's ear they all rejoice
> And utter forth a glorious voice
> Forever singing as they shine,
> The hand that made us is divine!"

Professor Newcomb was always religiously inclined, though he never became a church communicant. For many years he attended the Presbyterian Church with his wife and family. And he was a firm believer in a future life. One of the great pleasures to which he looked forward was that of meeting such men as Hipparchus, Copernicus, Newton and others who had gone before.

Professor Newcomb was the oldest of seven children. Two brothers and two sisters survived him.

In 1863, he married Miss Mary Caroline Hassler, daughter of Dr. Hassler, of the U. S. Navy, who lost his life in the wreck of the steamer *Atlantic*. Her grandfather was Ferdinand Rudolph Hassler, founder and first superintendent of the U. S. Coast Survey.

A widow, three daughters and eleven grandchildren survive him. An only son died in infancy. After a protracted and very painful

illness, Professor Newcomb passed away July 13, 1909, leaving as a heritage to his family and his country, the memory of

> One of those few immortal names
> That were not born to die.

I now have the pleasure of inviting your attention to this portrait, by C. H. L. Macdonald, in which you will recognize the features of our late vice-president. Its presence here is due to the liberality of a number of our fellow members who believe that in thus honoring the memory of Professor Newcomb they are at the same time honoring themselves.

Mr. chairman, in behalf of the committee having this matter in charge, I beg to present this portrait to the Philosophical Society, not doubting that it will be considered worthy of a place beside those of Franklin and Rittenhouse and of these other distinguished men who, in various activities, have contributed so greatly to the glory of this society and of the nation.

C. L. DOOLITTLE.

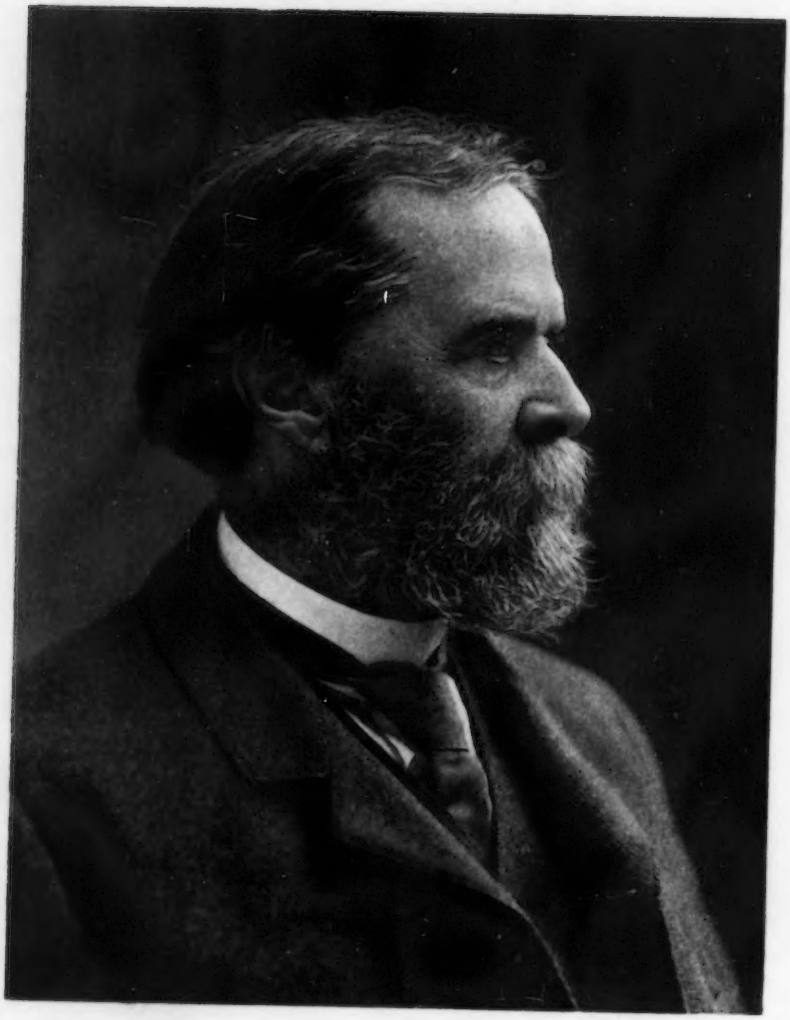
VICE-PRESIDENT PICKERING, in receiving the portrait, spoke substantially as follows:

It is difficult to add to the statement just made, and to those of others, any new facts regarding the life of Simon Newcomb. I could only tell you of personal recollections which would not be in place here. Our friendship, extending over forty years, was enlivened by many differences of opinion, but never marred by hard words or unkind feelings. It was never safe for anyone to make an absolute statement to Newcomb unless they were prepared to defend it by established facts.

A striking characteristic of the work of Newcomb was its versatility. Both astronomers and mathematicians regarded him as a leader, while his contributions to philosophy, to political economy and to other sciences were numerous and valuable. It was curious to see how, after devoting a life to the older astronomy, he became deeply interested in astrophysics, at an age when many men cease to do useful work.

The excellent portrait before you is especially welcome, since it is the gift of many, not of a few, of his admirers. As it hangs on the walls of this room it should serve as a model to us all. What happier lot can be asked for a man who, after retirement for age from the service of the United States, could continue his work with the greatest vigor, could live to see the greater part of it completed, and who retained his intellectual powers to the end?

In the name of the American Philosophical Society, I accept this gift to it, and tender the thanks of the members to the donors.



Robert Gibbs

OLIVER WOLCOTT GIBBS, 1822–1908.[1]

(Read May 20, 1910.)

The father of Wolcott Gibbs, Col. George Gibbs, was a man of some wealth. Possessed of much talent, and of much culture, brilliant in conversation, of polished manners, and with a wide experience of men and life, he was one of the marked men of his day. His beautiful place at the northwest angle of Long Island, with its front on East River at one of its most picturesque points, was one of the landmarks of the river. This large mansion at Sunswick Farms, near Hellgate Ferry, was the seat of an elegant hospitality somewhat rare in this country at the time in question: within was a fine library and a collection of minerals, for Col. Gibbs was an enthusiastic mineralogist. He was for many years a vice-president of a geological society which met at New Haven, and his donations of valuable specimens to that as well as to other mineralogical societies were frequent. During travel in Europe, he purchased a large collection of minerals, which, in the years from 1810 to 1812, was arranged at New Haven. The use of this collection was freely given to Yale College up to the year 1825, when the college purchased it. Once meeting the elder Silliman in the steamer *Fulton,* on Long Island Sound, he suggested to the latter the establishment of the *American Journal of Science,* and urged it with a zeal which was successful. To the first and second volumes of the new journal, he contributed four notes and brief papers. The mineral Gibbsite was named in his honor, and his name is preserved in Rafinesque's curious "Manual of the Grape, etc." as that of a public benefactor who had, before 1825, established one of the earliest vineyards in the attempt to introduce European wine-grapes into this country; and it appears also in lists of agricultural competitions.

[1] The writer, not now having convenient access to a chemical library, has depended for facts upon Clarke's "Wolcott Gibbs Memorial Lecture" to an unusually large extent.

Laura (Wolcott) Gibbs, the mother of Wolcott Gibbs, was a daughter of Oliver Wolcott, Secretary of the Treasury from 1795 to 1800, under Washington and Adams; afterwards justice of the United States Circuit Court, and, for the last eleven years of his life, governor of Connecticut. Her grandfather, Oliver Wolcott was brigadier general of Connecticut militia, member of the Continental Congress, and a signer of the Declaration of Independence, and lieutenant governor and governor of Connecticut. Her great-grandfather, Roger Wolcott, was major general of the army which captured Louisberg in 1745, being second in command at the siege, and was afterwards governor of the colony of Connecticut.

An older brother of Wolcott Gibbs was named George Gibbs. He early acquired a taste for natural history, so that, before he was twenty, he had made and mounted a collection of birds. After some years of travel, he studied law, and opened an office for the practice of the law in New York. He was for many years the librarian of the New York Historical Society; in 1846 he published "Memoirs of the Administrations of Washington and John Adams, edited from the papers of Oliver Wolcott, Secretary of the Treasury." He was appointed collector for Astoria in 1854. Residence here naturally gave him an opportunity for geological and for ethnologic and linguistic studies; in 1857, he accompanied an exploring expedition as botanist and geologist. Later, he served on a boundary commission. He edited, for the Smithsonian Institution, a large collection of documents relating to the ethnology and philology of certain Indian tribes.

Wolcott Gibbs was born in New York City, February 21, 1822. His parents gave him the name Oliver Wolcott, but he dropped the first name on entering adult life. His early days were spent mostly at Sunswick Farms. At the age of seven years, he was sent to a private school at Boston, where he was in the care of a maiden aunt. Some part of his vacations were spent at Newport, R. I., in the house of the distinguished Unitarian divine, William Ellery Channing. When he was about eleven years in age, his father died; his mother survived her husband by more than thirty-five years, and her strong character, and the great abilities which she had

inherited from the remarkable Connecticut family from which she was descended, furnished the lad with the guidance and the home influences suitable for his healthy development. At the age of twelve years, he returned to New York and prepared for college. In three years, he entered the freshman class of Columbia College, and was graduated in 1841, at the age of nineteen years. In the year before his graduation, he published the description of a new form of galvanic battery, in which carbon was used for the inactive plate; the young undergraduate publishing the discovery in the same year as Cooper and Schoenbein. The impulse towards such studies is to be found in the early life on his father's estate and in a father's example and other influence; but from the teaching of Renwick, then professor of physics and chemistry at Columbia College, a student like young Gibbs doubtless obtained much which was of value.

In the class of 1841, in which Wolcott Gibbs was graduated, there were at some time forty-nine men, of whom thirty-one took their bachelor's degree. Among these thirty-one, the most distinguished, after Wolcott Gibbs were: Duffield, senator for the Third Senatorial District of Michigan, brigadier general, United States Volunteers, 1863–1864, and superintendent of the United States Coast and Geodetic Survey, 1894–1898; and Emott, mayor of Poughkeepsie, justice of the Superior Court of New York, 1855–1863, and the judge of the Court of Appeals till his death in 1884. Among those who did not take the final degree was William H. Vanderbilt, who died in 1885.

After graduation, Wolcott Gibbs served for some months as assistant to Robert Hare, the inventor of the compound blowpipe, who was professor of chemistry in the Medical School of the University of Pennsylvania. After obtaining here an experience certain to be useful in fitting him for such a professorship, he entered the College of Physicians and Surgeons in New York, and received the degree of doctor of medicine in 1845. There is not much reason to suppose that Gibbs ever expected to practice medicine, for his next step shows that the study of chemistry had become the main purpose of his life. He went to Germany to secure such in-

struction in chemistry as was not then organized in this country. He first spent some months with Rammelsberg in Berlin, then studied for a year under Heinrich Rose, and then for some months under Liebig at Giessen. Lectures by Laurent, Dumas and Regnault marked the close of his days of travel and study, and in 1848, he returned to America. Among all these great teachers, it was Rose, whom he greatly admired, who seems most to have put his impress on Gibbs, and it may well be that from Rose came the preponderant inclination towards analytical and inorganic chemistry. But the young student who put himself under the instruction of the great leaders of organic chemistry, and of inorganic chemistry, and of theoretical chemistry and of physical chemistry, had already qualities from which were easily developed the breadth of view and of interest in very various kinds of research which always marked Gibbs.

He was soon appointed professor of chemistry in the New York Free Academy, now the College of the City of New York. The teaching required was elementary, and his activities accordingly overflowed in various channels. In the year 1851 he became associate editor of Silliman's *American Journal of Science,* to the establishment of which his father had contributed. To the succeeding forty-five volumes of this journal, Gibbs contributed 472 pages containing abstracts of 605 investigations on chemical and physical matters which had been published in Europe. The careful selection and the clear and accurate reports of these papers were a great service to American science. In 1852, Gibbs discovered a salt of xanthocobalt, a new cobaltamine; which led to important work, published in 1857, in collaboration with Genth. In 1861, he published the first of his papers on the analytical chemistry of the platinum metals. The considerable amount of the works, and especially the masterly ability shown in the paper on the cobalt bases, put Gibbs easily in the front rank of American chemists.

In 1863, Gibbs was appointed Rumford Professor of the Application of Science to the Useful Arts. He was expected to lecture on heat and light, and also to take charge of the chemical laboratory of the Lawrence Scientific School. As this was a position in which

little elementary instruction was required, the opportunity for usefulness to his students and to science generally were great. Association with such men as Louis Agassiz, the zoölogist, and Asa Gray, the botanist, and Jeffries Wyman, the comparative anatomist, and Benjamin Peirce, the mathematician, and Josiah Parsons Cooke, the chemist, together with their equals in other fields than scientific, made the position altogether delightful.

Dr. Gibbs remained in charge of the chemical laboratory of the Lawrence Scientific School for eight years. During this time his researches were naturally in great part directed to analytical methods, for he was training men who were to become chemists, some of whom were to gain a livelihood by being analytical chemists. The number of students in the laboratory was not large, some of these were qualified to assist Gibbs in his experimental researches. There was an assistant to take the burden of much routine work, and lectures on thermodynamics cost but little effort. The position was accordingly specially advantageous for one who would devote himself to chemical research.

Some one of the many distinguished chemists who were pupils of Gibbs in the Lawrence Scientific School could have spoken from personal knowledge of him as a teacher; but the choice of your president fell upon me, and it would only be some serious disability which would justify any American chemist in declining to voice the honor in which all of them hold Wolcott Gibbs. Since some expression of opinion and of feeling from those who came in close personal contact with him ought not to be omitted, it is fitting that the words in which one of the most distinguished of his pupils should be cited here. Clarke, chief chemist of the United States Geological Survey says:

> Most of the students had already gained some elementary knowledge of chemistry; their work began with the usual practice in analytical methods and chemical manipulations, and as the men showed capacity they were admitted to the confidence of their master and aided him in his investigations. This procedure may seem commonplace enough today, but in the years of which I speak it was new to American institutions and was looked upon doubtfully by some. . . . The real examinations under Gibbs were daily interviews, when he visited each student at his laboratory table and questioned him about his work. This, together with the reported analyses, gave the

teacher a clear conception of the true standing of each man. The fewness of the pupils was a distinct advantage, for all worked together in one room, beginners and research students often side by side. The result was that they learned much from one another, and there were many discussions among them over the chemical problems of the day. The men were taught to think for themselves, laying thereby a foundation for professional success which was pretty substantial. The course of instruction had no definite term of years prescribed for it, and graduation came whenever the individual had done the required amount of work, and submitted an acceptable original thesis. The final examination was usually oral, each man alone with his teacher, and was conducted in an easy conversational way which tended to establish the confidence of the candidate from the very beginning. In my own case, I remember that the questions covered a fairly broad range of chemical topics, and at the end of it, Dr. Gibbs drew me into a sort of discussion or argument with him over the then modern doctrine of valence. I now see that his purpose was not merely to ascertain what I had read on the subject, but what I really thought about it, if indeed I was entitled to think at all. Gibbs invariably treated his students, not as so many vessels into which knowledge was to be poured, but as reasonable beings, with definite purposes, to whom his help must be given. The research work in which the advanced students shared, and for which they received public credit, served to teach them that chemistry was a living and growing subject, and to train them in the art of solving unsolved problems.

What was there at all unusual in his teaching? Nothing, perhaps, from a modern point of view, but much that was new in America in the middle sixties. It was Gibbs's merit that he, more than any other one man, introduced into the United States the German conception of research as a means of chemical instruction, a conception which is now taken as a matter of course without thought of its origin. Gibbs worked with small resources and with no help from the outside; he was a reformer who never preached reform; his students rarely suspected that they were doing anything out of the ordinary; but they had the utmost confidence in their master, and took it for granted that his methods were sound. . . . The success of his students is perhaps the best monument to his memory.

In 1871, the chemical instruction in the Lawrence Scientific School was consolidated with that in Harvard College. This elicited vigorous protests from leading scientific journals, from scientific men, and from Professor Gibbs himself, but to no purpose. His duties henceforth were limited to his lectures on the spectroscope and on thermodynamics. He no longer had a laboratory in which to work, nor students, some of whom could assist in his researches. Contact with a great teacher was no longer a source of inspiration to students ready to profit by it. He himself had

more time for private research, but fewer facilities for it. Fortunately he had means enabling him to establish a small private laboratory, and to employ an assistant. It was in this laboratory, first at Cambridge and afterwards at Newport, that he carried out that one of all his researches which was the most important and elaborate and extensive.

The equipment of this laboratory was modest and very suitable for the work done in it. An ordinary kitchen stove served conveniently for the drying of precipitates in its oven, and the ignition of crucibles buried in the burning coal, and the heating or evaporation of liquids on its top. These processes were going on for much of the time during many years. There are kinds of work for which refined and elaborate apparatus barely accomplishes what is needful; if Gibbs had been occupied with work of this character, he would have provided it. There are not many things remaining which can be done with the iron spoon and gun-barrel which so well served Priestley; it happened that Gibbs, in his great work on the complex inorganic acids, was busy in a region very different from the determination of residuals which demands the utmost instrumental refinement, and his keen good sense suited the equipment to its purpose.

After the closing of the chemical laboratory of the Lawrence Scientific School, Dr. Gibbs lectured to small classes on the spectroscope and on thermodynamics till 1887, when he retired as professor emeritus. After this, he lived at Newport, where he had before spent summer vacations. His private laboratory was reëstablished here, and he continued his researches a long as health and strength sufficed. Some of his hours of recreation were spent in his flower garden, and his roses were much admired. He passed away on the ninth of December, 1908, at the age of eighty-six years nine and a half months. His wife, whose name was Josephine Mauran, died several years earlier, leaving no children.

It remains to speak briefly of Gibbs's scientific work. Fitly to describe it, even to an audience of chemists, would take more time than our traditions in the American Philosophical Society allow, so it is the esteem in which the work is held rather than the details of the work which will occupy us.

The infinite variety of careers for which variety of native powers and accidental advantages and opportunity open before us commonly involves at the beginning of active life a period of effort which is more or less tentative. Gibbs was no exception to this rule, but the period of tentative effort was brief, including, perhaps, only the first half dozen of his scientific papers. It is worthy of note that these show a somewhat wide range of interest and capacity.

His first scientific paper, published while in the junior class of Columbia College, was entitled "Description of a New Form of Magneto-Electric Machine, and an Account of a Carbon Battery of Considerable Energy." While a student in the medical college, he published a discussion of the theory of compund salt radicals. While a student in Germany, he published several mineral analyses. Just before becoming professor of chemistry in the New York City Free Academy, he showed that color changes produced by heat are in the direction of the less refrangible end of the spectrum. In 1852, he published the first of his papers on analytical methods. In 1853, he prepared an arsenical derivative of valeric acid. None of this work was of commanding importance, but it was of good quality, and it well illustrates Gibbs's knowledge of, and power of interesting himself in, somewhat widely varied departments of his chosen science.

The work to be mentioned next was worthy of the powers of any chemist in the world, and gave to him an established reputation and an honorable place among the leaders of chemistry. During the years to which allusion has just been made, he had been at work on a new cobaltamine, and, in 1856, he published a great research which commanded general recognition of the abilities of a master. A salt of the first known of the cobaltamines had been prepared by Gmelin in the year in which Gibbs was born, but it was some time before its true nature was understood. In 1847, Genth, then a student in Germany, prepared other related compounds and was the first rightly to understand their composition. Two French chemists working independently came to conclusions like those of Genth; he had established the composition of the two cobaltamines now called

luteocobalt and roseocobalt. Gibbs in 1852 established the composition of a third and new cobaltamine now called xanthocobalt, and the two American chemists naturally were led to work in concert. In 1856 they published their celebrated memoir, describing no less than 35 salts of these three cobaltamines, together with some of those of a fourth called purpureocobalt. They gave adequate analyses of these salts, together with crystallographic measurements, by J. D. Dana, of eleven of them. Purpureocobalt was then first distinguished from roseocobalt, though the conception then attained of the precise nature of the difference was not final. Gibbs attempted a discussion of the constitution of these bases, but prematurely. Adequate theories of structure were yet to be developed; when such development came, the facts established by Gibbs and Genth formed a solid foundation for the brilliant superstructure. Eleven years after this paper, Gibbs himself made an attempt to establish the theory of the structure of these amines. The conception utilized by Gibbs was also utilized two years later by one of the leaders in the establishment of the doctrines of structural chemistry; these views have now given way to other views which harmonize better with a wider range of facts; but the discussion of tentative possible explanations of facts is one of the steps by which the truth is finally discovered. Gibbs utilized his hypothesis of the structure of the cobaltamines in further papers in 1876 and 1877, in which he described many more salts, some of these being salts of a fifth amine called croceocobalt. The whole was a great piece of valuable and most fruitful work, carried on with extraordinary ability and success.

The work on the platinum metals, published from 1861 to 1864, related mainly to analytical methods. In 1871, he published a brief note on a remarkable compound of iridium, and in 1881, he described a new basic compound of osmium. But these researches had to be discontinued for lack of suitable facilities.

Gibbs was a man fertile in varied suggestions; in many a conversation he would lavish freely material almost sufficient for the working capital of a teacher who taught largely by inspiring and directing research. It was natural, therefore, that besides the great

work on the cobalt bases and another greater work yet to be mentioned, he should publish many papers of less extent. From the hand of such a master, these papers are valuable and important. Many relate to analytical methods; many relate to the analytical methods of the platinum metals, or to new compounds of the platinum metals. These papers are numerous; most of them are too technical for presentation here, but one of them is especially worthy to be mentioned and to be mentioned in this city. The electrolytic determination of copper was first published from the laboratory of the Lawrence Scientific School and the whole field of electro-chemical analysis, nowhere cultivated more successfully than in Philadelphia, was opened by Gibbs. In collaboration with E. R. Taylor, he devised filters composed of insoluble powders like glass and sand; then Munroe, another student, invented porous porcelain cones for filtration, and Gooch, an assistant of Gibbs, invented perforated crucibles with filters composed of layers of asbestos fibre made into a felt, in place of which we now often use spongy platinum. So the use of filters which do not change weight on ignition and which do not require us to heat reducible substances in contact with carbon, is due to Gibbs.

The most remarkable work of Gibbs is contained in his series of researches on the complex inorganic acids, whose publication began in 1877 and was continued till after 1890. Some complex inorganic acids were already well known; for instance, phosphomolybdates are in common use. But, in his first paper, Gibbs showed that, far from being exceptional compounds, they were members of an extensive class; that the formation of complex acids was characteristic of tungstates and molybdates to an extraordinary degree; and that the possible number of such compounds was vast. After this preliminary announcement, Gibbs determined the true composition of the sodium tungstates. Then he prepared phosphotungstates and phosphomolybdates, and similar compounds with arsenic in place of phosphorus. From this beginning, the work developed in directions which cannot be well described except to an audience of chemists; taking in all the degrees of oxidation of phosphorus, with all the known variations in the amount of replaceable hydrogen

in its numerous acids. Then were described complex acids with not two but three acid radicals in the complex, like that of the stannophosphotungstates. Next, other elements like platinum, selenium, tellurium, cerium, uranium, were drawn into like complex acids. On salt, phosphovanadiovanadicotungstate of barium, $60WO_3$, $3P_2O_5$, V_2O_5, VO_2, $18BaO$, $150H_2O$, had an atomic weight of 20,066 and a complication the interpretation of which seems almost incredibly difficult. Salts of over fifty such complex acids were described, and all this immense volume of work was accomplished in a small private laboratory with only one assistant.

In his address as president of the American Association for the Advancement of Science in 1898, Gibbs spoke on the complex inorganic acids. That the views then presented were final was not to be expected. Even to establish a simple matter like the composition of water, expressed in three characters, required, if we may agree with Kopp, no less than the joint efforts of three men. In the case which we have to consider, one man was working alone in a wilderness to be compared, both for extent and for complexity, not to a simple problem in inorganic chemistry, but to some great section of organic chemistry. But though working alone, he mapped out the wilderness so that he who will may now survey it at his ease. We are now in possession of methods which would have been of great service in this reconnoissance, had they been developed early enough. The cryoscopic or the ebullioscopic method of determining molecular weights would have helped to ascertain whether a given body was a compound of a basic radical with a single complex acid radical or with two simple acid radicals. Electrical methods might have assisted in ascertaining the composition of a complex ion. But these methods by means of which physical chemistry has made so great conquests were not ready to be used when Gibbs worked, and, accordingly, his survey does not include some facts and some conclusions which they might establish. So Newton had no spectroscope to use. But that the work of Gibbs was less valuable for this reason, few chemists would be willing to admit. He put before us a great and difficult problem and he did, towards its solution, more than almost any other man could have done.

It has been indicated that Gibbs had a wide range of insight and interest. He did no considerable work in organic chemistry, but he did not entirely neglect it. Lecturing as he did upon heat and light, and writing as he did for twenty-three years the abstracts of physical researches which appeared in the *American Journal of Science*, he had a knowledge of and an interest in, physical subjects which was expressed in several papers on optical matters. Serious work on atomic weights was carried on in his laboratory and under his direction, where three important determinations were made; he also devised a method of determining some atomic weights which had before been rather difficult to obtain. He published this method after he was seventy years of age, and the method has since been applied by others with good success. Processes requiring refinement and consummate accuracy were attractive to him, as well as some in which refinement and final accuracy are to be attained by some future generation. In an important study of the physiological effects of isomeric organic compounds on animals, he utilized his early medical training.

All Gibbs's activities were actuated by very high ideals. He was little known by the public at large, even by the best part of the public, but was greatly honored among scientific men. He was one of the founders and original members of the National Academy of Sciences and for some years was its president. He was president of the American Association for the Advancement of Science in 1897–1898. He was an honorary member of the three great chemical societies of the world and of the Prussian Academy of Science, and several universities gave him honorary degrees. He was a devoted scholar, glad to give his best efforts to the world, highly valuing unsought approval, and never seeking other reward. He was during the civil war, for several years an earnest and active member of the Sanitary Commission. It was he who first suggested that the ideas on which the Sanitary Commission was founded ought to take the form of a club, and it was at a meeting in his house that the Union League Club was established.

In the words of Clarke:

> Gibbs was a man of striking personality, tall, erect and dignified. As with most men of positive character, he had strong likes and dislikes, but

the latter never assumed unworthy form. To his friends he was warmly devoted, and always ready to help them in their work with manifold suggestions. His breadth of mind is indicated by the range of his researches, and his liberality by the way in which he encouraged his students to develop his ideas. More than one important investigation was based upon hints received from him, and was carried out under his supervision, to appear later under another name. Gibbs never absorbed the credit due even in part to others, nor failed to recognize the merits of his assistants in the fullest way. Had he been more selfish, his list of publications would have been lengthened; but his sense of justice was most keen, and therefore he held the esteem and confidence of his co-workers. No man, not even among his opponents, for such there were, could ever accuse him of unfairness. He deserved all honor, and his name will long live in the history of that science to which his life was given.

EDWARD W. MORLEY.

MINUTES.

MINUTES.

Stated Meeting, January 7, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

A communication was received from the Committee of Organization of the 3me Congrès International de Botanique announcing that the Congress will be held in Brussels from the fourteenth to the twenty-second of May and inviting the Society to be represented thereat.

The decease was announced of:

Dr. Enrico Hillyer Giglioli, at Florence, on December 16, 1909, æt. 64.

Mr. Israel W. Morris, at Philadelphia, on December 18, 1909, æt. 76.

Dr. Charles Benjamin Dudley, at Altoona, Pa., on December 21, 1909, æt. 67.

Prof. J. C. Branner read a paper on "The Geology of the Black Diamond Regions of Bahia, Brazil."

The judges of the annual election of officers and councillors held on this day, between the hours of two and five in the afternoon, reported that the following named persons were elected, according to the laws, regulations and ordinances of the Society, to be the officers for the ensuing year.

President:

William W. Keen.

Vice-Presidents:

William B. Scott, Albert A. Michelson, Edward C. Pickering.

Secretaries:

I. Minis Hays, James W. Holland,
Arthur W. Goodspeed, Amos P. Brown.

Curators:

Charles L. Doolittle, William P. Wilson, Leslie W. Miller.

Treasurer:

Henry La Barre Jayne.

Councillors:

(*To serve for three years.*)

Edward L. Nichols, Ernest W. Brown,
Samuel Dickson, Morris Jastrow, Jr.

Stated Meeting, January 21, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Dr. W. W. Keen read a paper on "Modern Antiseptic Method and the Rôle of Experiment in its Discovery and Development."

Stated Meeting, February 4, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

The decease was announced of Hon. Edward Patterson, at New York, January 28, 1910, æt. 70.

The following papers were read:

"Notes on some Pseudomorphs, Petrifactions and Alterations," by Austin F. Rogers, Ph.D. (Introduced by Prof. J. C. Branner.)

"The Influence of Mental and Muscular Work on Nutritive Processes," by Prof. Francis B. Benedict. (Introduced by Dr. W. W. Keen.)

Stated Meeting, February 18, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

The decease was announced of Prof. Dr. Friedrich Kohlrausch, æt. 70.

Mr. J. Vipond Davies (introduced by Dr. W. W. Keen) read a paper on "The Tunnel Construction of the Hudson and Manhattan Railroad Company."

Stated Meeting, March 4, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Dr. Samuel W. Stratton read a paper on "The Work of the National Bureau of Standards."

Stated Meeting, March 18, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

The decease was announced of Dr. Wharton Sinkler, at Philadelphia, on March 16, 1910, æt. 65.

Dr. Jay F. Schamburg (introduced by Dr. W. W. Keen) read a paper on "Vaccination and the Ravages of Small-pox among Royal and Noble Families."

Stated Meeting, April 1, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

The decease was announced of Prof. Alexander Agassiz, at sea, on March 28, 1910, æt. 74.

Mr. David Fairchild read a paper entitled "A New World for Exploration."

General Meeting, April 21, 22 and 23, 1910.

Thursday, April 21. Opening Session—2 o'clock.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Invitations were received:

From the XI^{e} Congrès Géologique International, to be represented at the Congress to be held at Stockholm on August 18–25, 1910.

From the President of the Argentine Scientific Society to be represented at the International American Scientific Congress to be held at Buenos Aires from July 10–25, 1910.

The decease was announced of:

Prof. George L. Vose, at Brunswick, Me., on March 30, 1910, æt. 79.

Prof. Robert Parr Whitfield, at New York, on April 6, 1910, æt. 82.

The following papers were read:

"The Great Japanese Embassy of 1860; The Forgotten Chapter in the History of International Amity and Commerce," by Patterson DuBois, of Philadelphia.

"The Government of the United States in Theory and Practice," by C. Stuart Patterson, of Philadelphia.

"Early Greek Theories of Sound and Consonance," by Wm. Romaine Newbold, Professor of Philosophy in the University of Pennsylvania.

"New Fields of German-American Research," by M. D. Larned, Director of the Institution of German-American Research, University of Pennsylvania.

"The Real Meaning of the Controversy concerning Pragmatism," by Albert Schinz, Associate Professor of French Literature in Bryn Mawr College, Pa. (Introduced by Mr. Harrison S. Morris.)

"Magical Observances in the Hindu Epic," by E. Washburn Hopkins, Professor of Sanskrit in Yale University, New Haven, Conn.

"The Bearded Venus," by Morris Jastrow, Jr., Professor of Semitic Languages in the University of Pennsylvania.

"Roman Mysticism in the Fourteenth Century," by Kuno Francke, Curator of the Germanic Museum, Harvard University, Cambridge.

"A German Monk of the Eleventh Century," by A. C. Howland, Assistant Professor of Mediæval History in the University of Pennsylvania. (Introduced by Professor Edward P. Cheyney.)

"The New Shakespeare Discoveries," by Felix E. Schelling, Professor of English Literature in the University of Pennsylvania.

Friday Morning, April 22. Executive Session—10 o'clock.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Mr. Edwin Swift Balch, on behalf of the Committee on Antarctic Exploration, presented the following report:

At the annual meeting of the American Philosophical Society, held on April 22, 1909, resolutions were passed, requesting the coöperation of the scientific and geographical societies of the United States to urge on the government to make sufficient appropriations to send a vessel under the direction of the Secretary of the Navy to reëxplore Wilkes Land.

These resolutions were embodied in a circular letter under date of May 20, 1909, sent to a number of scientific organizations, and they elicited favorable response by the following societies:

The American Academy of Arts and Sciences, Boston.
The American Geographical Society, New York.
The California Academy of Sciences, San Francisco.
The New York Academy of Sciences.
The Franklin Institute, Philadelphia.
The Geographical Society of Philadelphia.
The American Museum of Natural History, New York.
The Buffalo Society of Natural Sciences.
The Geological Society of America.
The Association of American Geographers.
The American Alpine Club.

At the meeting of the American Philosophical Society held on November 5, 1909, a Committee on Antarctic Exploration was appointed consisting of the following:

Edwin Swift Balch, *Chairman.*
Henry Grier Bryant.
Dr. Hermon C. Bumpus.
Professor William Morris Davis.
Rear Admiral George W. Melville, U.S.N.

Professor Henry Fairfield Osborn.

Dr. Charles D. Walcott.

The Committee met on Friday, November 19, 1909. Dr. Bumpus suggested that the "Albatross" might be assigned to work in the Antarctic by the Bureau of Fisheries. Admiral Melville urged trying to get either the "Bear" or the "Thetis" detailed for this service. The Committee finally decided to approach the Secretary of the Navy directly.

Dr. Walcott arranged for a meeting of the Committee with Admiral Pillsbury, representing the Secretary of the Navy, and at this meeting, on December 20, 1909, Admiral Pillsbury advised writing a letter, explaining the matter fully, to the Secretary of the Navy. This was done, and on January 4, 1910, this letter, signed by all the members of the Committee, was sent to the Secretary of the Navy. On January 15 an answer was received from the Secretary of the Navy, stating that he would bring the matter to the attention of the President at an early date.

Admiral Pillsbury, at the direction of the Secretary of the Navy, prepared estimates as to the expense of outfitting an expedition to Wilkes Land. He made inquiries on the Pacific coast and in Newfoundland about whaling ships, but found none suitable for the purpose. He also got estimates for building a ship.

About this time it was reported that the "Roosevelt" was for sale; and from unofficial information received, it seemed possible that her owners might be willing to loan her or rent her. The chairman, then, on January 24, 1910, sent a letter to her owners, the Peary Arctic Club, asking whether the club would be willing to loan her to the Government for an expedition to Wilkes Land. No direct answer to this letter, however, was ever received.

The American Geographical Society cordially coöperated to induce the Government to send this expedition to Wilkes Land. Messrs. Archer M. Huntington, Chandler Robbins, Hamilton Fish Kean and Cyrus C. Adams, especially, urged the matter on the Secretary of the Navy.

It was finally decided by the President that it was not advisable at this time to ask Congress for an appropriation for this purpose.

The main object of the resolutions of the American Philosophical Society, therefore, has not been accomplished as yet. Nevertheless the resolutions have borne fruit.

The National Geographic Society and the Peary Arctic Club are preparing jointly an expedition to the Antarctic. The National Geographic Society did not acquiesce in the request to urge the Government to send an expedition to Wilkes Land. But General Greely informed your chairman last summer that, after the resolutions of the American Philosophical Society were received, he brought the matter up at a Board meeting; that it was agreed that it was of national importance; that the sentiment was against approaching Congress for an appropriation; that it was decided to take steps to raise a national fund; and that General Greely himself was appointed chairman of the committee for the purpose. Nothing further appears to have been done after this until the Peary Arctic Club suggested a joint expedition. While this latter expedition therefore is entirely independent of the one suggested in the resolutions of April, 1909, and has been evolved on different lines; nevertheless it is all an expression of a national desire and a part of the same movement for Antarctic exploration, and your Committee wishes heartily for its complete success.

An important direct result of the movement has been the getting of certain nomenclature about the Antarctic placed on the official charts of the Hydrographic Office. Admiral Pillsbury brought a preliminary drawing of a circumpolar chart of the southern hemisphere to the conference with your Committee on December 20, 1909. The Chairman of the Committee had some correspondence with the hydrographer, Captain A. G. Winterhalter, about this chart, and suggested placing the names "West Antarctica," "East Antarctica," "Wilkes Land" and "Palmer Land" on it. These suggestions were accepted by the Navy Department, and the names placed on a "Circumpolar Chart of the Southern Hemisphere" published on February 21, 1910.

Perhaps the most important result of the movement, however, is the arousing of interest in America about the Antarctic. Since the return of the expedition led by Lieutenant Wilkes, American interest

in the south polar regions has been dormant. Now many scientific men and societies are awake and interested. Let us hope this interest will grow and, perhaps, in the years to come, lead to the gathering of more scientific and geographic data about the still unknown south, and to the sending of an American expedition to Wilkes Land, to explore it and establish beyond question the geographical discoveries reported by Lieutenant Wilkes, in command of the U. S. Exploring Expedition of 1838–1843. It would seem wise to continue the committee with instructions to prepare a renewed application to the Government and continue the dissemination of interest in this great undertaking.

The report was accepted and the Committee continued.

Morning Session, 10.05 o'clock.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

The following papers were read:

"Physical Notes on Meteor Crater, Arizona," by William F. Magie, Professor of Physics at Princeton University.

"The Conversion of the Energy of Carbon into Electrical Energy on Solution in Iron," by Paul R. Heyl, Assistant Professor of Physics in the Central High School, Philadelphia. (Introduced by Prof. Harry F. Keller.)

"The One Fluid Theory of Electricity," by Francis E. Nipher, Professor of Physics in Washington University, St. Louis.

"The Past and Present Status of the Ether," by Arthur Gordon Webster, Professor of Physics at Clark University, Worcester.

"The Ether Drift," by Augustus Trowbridge, Professor of Physics at Princeton University.

"The Effects of Temperature on Fluorescence and Phosphorescence," by E. L. Nichols, Professor of Physics at Cornell University, Ithaca.

"Infra-red and Ultra-violet Landscapes."

"New Optical Properties of Mercury Vapor."

"Newton's Rings as Zone-plates," by Robert Williams Wood, Professor of Experimental Physics at Johns Hopkins University, Baltimore.

"New Surgery of the Viscera of the Chest," by Alexis Carrel, Associate Member of the Rockefeller Institute for Medical Research, New York.

"Experimental Poliomyelitis in Monkeys," by Simon Flexner, Director of Laboratories of Rockefeller Institute for Medical Research, New York.

"Description of the Brain of an Eminent Chemist and Geologist (a member of this society)—a note Concerning the Size of the Callosum in Notable Persons," by E. A. Spitzka, Professor of General Anatomy in Jefferson Medical College, Philadelphia.

"A Brain of about One Half the Average Weight from an Intelligent White Man," by Burt G. Wilder, Professor of Neurology and Vertebrate Zoölogy in Cornell University, Ithaca, N. Y.

Afternoon Session—2 o'clock.

WILLIAM B. SCOTT, Ph.D., LL.D., Vice-President, in the Chair.

The following papers were read:

"Characteristics of Existing Continental Glaciers," by William H. Hobbs, Professor of Geology in University of Michigan, Ann Arbor.

"Dermal Bones of Paramylodon from the Asphaltum Deposits of Rancho la Brea, near Los Angeles, Cal."

"The Restored Skeleton of *Leptauchenia decora*," by William J. Sinclair, Instructor in Geology in Princeton University. (Introduced by Professor W. B. Scott.)

"Correlation of the Pleistocene of the New and Old Worlds," by Henry Fairfield Osborn, President of the American Museum of Natural History, New York.

"The Primates of the Old and the New Worlds, together with Man," by Giuseppe Sergi, Professor of Anthropology in the University of Rome, Italy.

"A Note on Antarctic Geology."

"The Italian Riviera—a Study in Geographical Description," by William Morris Davis, Professor of Geology in Harvard University, Cambridge.

"Some Recent Results in Connection with the Absorption Spectra of Solutions," by Harry C. Jones, Professor of Physical Chemistry in Johns Hopkins University. (Introduced by Dr. James W. Holland.)

"The Propagation of Explosions in Mixtures of Petroleum Vapor with Air in Tubes," by Charles E. Munroe, Professor of Chemistry in George Washington University, Washington, D. C.

"What Constitutes a Species in *Agave*," by William Trelease, Director of the Missouri Botanical Garden, St. Louis.

"The Suppresion and Extension of Sporogenous Tissue in *Piper Betel*," by D. S. Johnson, Professor of Botany in Johns Hopkins University, Baltimore. (Introduced by Professor John W. Harshberger.)

"A Method of Using the Microscope," by N. A. Cobb, Crop Technologist in charge of Agricultural Technology, Bureau of Plant Industry, Dept. of Agriculture, Washington. (Introduced by Professor John W. Harshberger.)

"The Use of the Hydrometer in Phytogeographic Work," by John W. Harshberger, Assistant-Professor of Botany in University of Pennsylvania, Philadelphia.

Friday Evening, April 22.—8.15 P. M.

Prof. George E. Hale, F.R.S., Director of the Solar Observatory of the Carnegie Institution, at Pasadena, Cal., gave an illustrated lecture on "The Work of the Mount Wilson Solar Observatory."

Saturday, April 23. Executive Session—9.30 o'clock.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Candidates for membership were balloted for, and the tellers, Secretary Holland and Dr. Charles Sedgwick Minot, reported the election of the following:

Residents of the United States.

Simeon Eben Baldwin, LL.D., New Haven.
Francis G. Benedict, Ph.D., Boston.
Charles Francis Brush, Ph.D., LL.D., Cleveland, Ohio.
Douglas Houghton Campbell, Ph.D., Palo Alto, Cal.
William Ernest Castle, Ph.D., Belmont, Mass.
George Byron Gordon, Philadelphia.
David Jayne Hill, LL.D., American Embassy, Berlin.
Harry Clary Jones, Ph.D., Baltimore.
Leo Loeb, M.D., Philadelphia.
James McCrea, Ardmore, Pa.
Richard Cockburn Maclaurin, F.R.S., LL.D. (Cantab.), Boston Mass.
Benjamin O. Peirce, Ph.D., Cambridge, Mass.
Harry Fielding Reid, Ph.D., Baltimore.
James Ford Rhodes, LL.D., Boston, Mass.
Owen Willans Richardson, M.A. (Cantab.), D.Sc. (Lond.), Princeton, N. J.

Foreign Residents.

Adolf von Baeyer, Ph.D., M.D., F.R.S., Munich.
Madame S. Curie, Paris.
Sir David Gill, K.C.B., Sc.D., LL.D., F.R.S., London.
Edward Meyer, Ph.D., LL.D., Berlin.
Charles Emile Picard, Paris.

Morning Session—10 o'clock.

Edward C. Pickering, LL.D., F.R.S., Vice-President, in the Chair.

The following papers were read:

"Solar Activity and Terrestrial Magnetic Disturbances" (second communication).

"Magnetic Results of the first Cruise of the 'Carnegie,' 1909–1910," by L. A. Bauer, Director of Department of Terrestrial Magnetism, Carnegie Institution, Washington.

"The New Tide-predicting Machine of the U. S. Coast and Geodetic Survey," by O. H. Tittman, Superintendent of the Survey.

"Spectra of Recent Comets," by Edwin B. Frost, Director of Yerkes Observatory, Williams Bay, Wis.

"On the Distances of Red Stars," by Henry Norris Russell, Assistant-Professor of Astronomy, Princeton University. (Introduced by Professor W. F. Magie.)

"A Standard System of Photographic Stellar Magnitudes," by Edward C. Pickering, Director of Harvard College Observatory, Cambridge.

"The Existence of Planets about the Fixed Stars."

"Results of Recent Researches in Cosmical Evolution," by T. J. J. See, U. S. Naval Observatory, Mare Island, Cal.

"Some Interesting Double Stars," by Eric Doolittle, Assistant-Professor of Astronomy in University of Pennsylvania.

"Radio-action in the Heavenly Bodies."

"Radio-action the Cause of Hale's Anomalous Solar Spectrum," by Monroe B. Snyder, Director of the Philadelphia Observatory.

"Certain Irregularities in the Problem of Several Bodies," by Edgar Odell Lovett, President of the William M. Rice Institute, Houston, Texas.

"Groups Generated by Two Operators, Each of which Transforms the Square of the Other into a Power of Itself," by George A. Miller, Professor of Mathematics in the University of Illinois. (Introduced by Professor C. L. Doolittle.)

"Obituary Notice of Simon Newcomb, F.R.S., LL.D., D.C.L., late Vice-President of the American Philosophical Society," by C. L. Doolittle, Director of the Flower Observatory of the University of Pennsylvania.

Presentation of a portrait of the late Vice-President Newcomb. Acceptance on behalf of the Society, by Vice-President Pickering.

Afternoon Session—2 o'clock.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Dr. Harry C. Jones, a newly-elected member, subscribed the laws and was admitted into the Society.

The following papers were read:

"The Origin of Our Alphabet and the Race of the Phenicians," by Paul Haupt, Professor of Semitic Languages in the Johns Hopkins University.

Symposium on Experimental Evolution:

"Inheritance in Non-sexual and Self-fertilized Organisms," by Herbert S. Jennings, Professor of Experimental Zoölogy in Johns Hopkins University, Baltimore.

"Germinal Analysis through Hybridization," by George H. Shull, Resident Investigator, Station for Experimental Evolution, Carnegie Institution of Washington, Cold Spring Harbor, N. Y. (Introduced by Dr. Charles B. Davenport.)

"New Views about Reversion," by Charles B. Davenport, Director of Station for Experimental Evolution, Carnegie Institution, Cold Spring Harbor, N. Y.

"Experimental Modification of the Germ Plasm," by William L. Tower, Assistant-Professor of Embryology in the University of Chicago. (Introduced by Dr. Henry H. Donaldson.)

Stated Meeting, May 6, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Letters accepting membership were read from:

Simeon Eben Baldwin, LL.D., New Haven.
Francis G. Benedict, Ph.D., Boston.
Charles Francis Brush, Ph.D., LL.D., Cleveland, Ohio.
Douglas Houghton Campbell, Ph.D., Palo Alto, Cal.
George Byron Gordon, Philadelphia.
Harry Clary Jones, Ph.D., Baltimore.
Leo Loeb, M.D., Philadelphia.
James McCrea, Ardmore, Pa.
Richard Cockburn Maclaurin, F.R.S., LL.D. (Cantab.), Boston, Mass.
Benjamin O. Peirce, Ph.D., Cambridge, Mass.
Harry Fielding Reid, Ph.D., Baltimore.

James Ford Rhodes, LL.D., Boston, Mass.

Owen Willans Richardson, M.A. (Cantab.) D.Sc. (Lond.), Princeton, N. J.

The decease was announced of Mr. John H. Converse, at Rosemont, Pa., on May 3, 1910, æt. 69.

The following papers were read:

"On the Radio-Active Substances," by Prof. Harry F. Keller.

"Further Notes on Burial Customs, Australia," by R. H. Mathews.

Special Meeting May 20, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Mr. James McCrea, a newly-elected member, signed the laws and was admitted into the Society.

Letters accepting membership were received from

Dr. William Ernest Castle.

Dr. Adolf von Baeyer.

Sir David Gill.

Dr. Eduard Meyer.

Prof. Charles Émile Picard.

The decease was announced of Sir William Huggins, K.C.B., F.R.S., at London on May 12, 1910, æt. 86.

Prof. Edward W. Morley read an obituary notice of Prof. Oliver Wolcott Gibbs.

Prof. Robert H. Hough read a paper on the "Principle of Relativity and its Significance."

Stated Meeting, October 7, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

Letters were received accepting membership from:

Prof. Francis G. Benedict,

Hon. David Jayne Hill, and

Mme. S. Curie.

Inviting the Society to be represented at the

Tenth International Geographical Congress, to be held at Rome in October, 1911.

Centenary of the Königliche Friedrich-Wilhelms Universitet, Berlin, in October, 1910.

First Universal Races Congress, to be held at London, in July, 1911.

Inauguration of Frank LeRend McVey, Ph.D., LL.D., as President of the University of North Dakota, in September, 1910.

The decease was announced of:

Prof. Mathaeus Much, at Vienna, on December 17, 1909, æt. 78.

Prof. William Phipps Blake, at Berkeley, Cal., on May 21, 1910, æt. 84.

Prof. George F. Barker, at Philadelphia, on May 24, 1910, æt. 74.

Mr. Joseph S. Harris, at Philadelphia, on June 2, 1910, æt. 74.

Prof. Giovanni Schiaperelli, at Milan, on July 4, 1910, æt. 75.

Hon. Craig Biddle, at Andalusia, Pa., on July 26, 1910, æt. 87.

Sig. Paolo Mantegazzo, at Spezia, on August 28, 1910, æt. 79.

Prof. Frederick Augustus Genth, at Lansdowne, Pa., on September 2, 1910, æt. 55.

Prof. William A. Lamberton, at Point Pleasant, N. J., on September 8, 1910, æt. 61.

Mr. Richard Wood, at Philadelphia, on September 29, 1910, æt. 76.

The following papers were read:

"On Suicide," by J. Chalmers Da Costa, M.D., discussed by Prof. L. M. Haupt.

"The Origin of Primitive Man in America," by Albert S. Ashmead.

Stated meeting, November 4, 1910.

WILLIAM W. KEEN, M.D., LL.D., President, in the Chair.

An invitation was received for the Society to be represented at the Twenty-fifth Anniversary of Bryn Mawr College, on October 21 and 22, 1910.

The decease was announced of:

Mr. Arthur Erwin Brown, at Philadelphia, on October 29, 1910, æt. 60.

The following papers were read:

"Further Considerations on the Origin of the Zone of Asteroids and on the Capture of Satellites," by Dr. T. J. J. See.

"Modern Physics," by President Ernest Fox Nichols, discussed by Profs. Trowbridge, Snyder, Doolittle and Goodspeed.

Stated meeting, December 2, 1910.

WILLIAM BERRYMAN SCOTT, ScD., LL.D., Vice-President, in the Chair.

The decease was announced of:

Prof. A. Marshall Elliott, at Baltimore, on November 9, 1910, æt. 66.

The following papers were read:

"Some Aspects of the Scientific Work of the U. S. Bureau of Fisheries," by Dr. Hugh M. Smith, discussed by Mr. Willcox, Dr. Holland, Mr. Jayne, Dr. Jastrow and Dr. Marshall.

"The True Atomic Weights of Oxygen and Silver," by Dr. Gustavus Hinrichs. (Communicated by Dr. J. W. Holland.)

"Propagation of Long Electric Waves Along Wires," by Prof. E. P. Adams. (Communicated by Prof. W. F. Magie.)